

**Feasibility Study**

**West Michigan  
Regional Liquid Livestock Manure Processing Center  
(LLMPC)**

**Final Report**

**Prepared For:**

**West Michigan Livestock Producer Group**

**Grant No.: PLA-04-59**

**Prepared By:**

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## **I. Executive Summary**

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### **A. Introduction**

Frazier Barnes and Associates (FBA) was contracted to conduct a feasibility study for the West Michigan Livestock Producer Group (WMLPG) to determine the viability of a centrally-located and regional Liquid Livestock Manure Processing Center (LLMPC) to manufacture high quality methane from liquid livestock manure. A regional plant needs to be properly located to minimize the transportation distance from liquid livestock manure feedstock suppliers. This project would determine if a regional LLMPC would have significantly larger economies of scale, lower capital cost, lower operating cost, higher product yields and improved product market access advantages that would offset higher transportation costs as compared to a farm-based anaerobic digester.

The WMLPG is a group of livestock producers interested in the regional anaerobic digestion concept and who are potential sources of liquid manure. WMLPG is not a formal organization yet and as such, has no address and no Federal ID number.

The companies and organization below contributed research and administration toward this study.

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### **B. Feedstock Summary**

A regional anaerobic digester has been proposed for Ottawa and Allegan Counties in Michigan. The proposed digester would process 100,000 gallons per day of swine manure collected from local swine producers. A survey conducted by Michigan State University determined there would be

sufficient swine manure within 20 miles to supply the proposed digester for it to operate at 100% capacity. The majority of the available swine manure is in farrow-finish and grow-finish operations. Most producers in the region would be interested in investing in the digester, if it proved a profitable venture.

Other feedstocks exist to supplement swine manure, although their use is limited by the cost, flexibility of the anaerobic digestion technology, and the methods of disposal allowed by Michigan law. These feedstocks include mortality (the carcasses of swine and other animals), offal from processing facilities, food wastes, corn stover, corn silage, and yard debris.

### **C. Technology Summary**

Anaerobic digestion is a process that has been used for centuries to process agricultural waste. The three main types of anaerobic digestion technology are lagoons, plug-flow, and complete mixed digesters. Complete mix anaerobic digesters were studied for this report. Complete mix systems are typically above-ground tanks that are sealed air-tight. Bacteria in the digester tank break down volatile solids in the swine manure to produce methane. This length of time for this process to take place, the Hydraulic Retention Time (HRT), takes from 3 to 20 days, depending upon the size of the digester, its type, and its operating temperature.

FBA received preliminary budget estimates for four complete mix type digester systems. The amount of biogas produced varied; generally, the higher the cost of the system, the higher the biogas output. Only three of the systems operate on 100% swine manure; the fourth must be supplemented with carbon sources to aid in digestion.

<b>Table 1: Technology Supplier Summary</b>				
	Waste Energy Solutions	RCM-Biothane	Andigen	Biopower Technologies
Total Solids Allowed in Digester	10%	10%	10%	7.5%
Capital Cost	\$12,478,363	\$6,353,750	\$4,581,232	\$3,744,259
Digester Type	Complete Mix	Upflow Anaerobic Sludge Blanket	Induced Blanket Reactor	Fixed-Film
Licensed System	Yes	No	Yes	Yes
Operating Temperature	Thermophilic	Mesophilic	Mesophilic	Mesophilic
Hydraulic Retention Time	14 days	3 days	5 days	3 to 5 days
Methane in Biogas	75%	65%	70%	65%

### **D. Product Summary**

The digester would produce two products: biogas and digestate. The biogas, which is 65% to 75% methane, would be sold to a local host and the digestate material marketed as a land applicant.

The West Michigan LLMPC has a potential host for the biogas at a site adjacent to the Autumn Hills Landfill near Holland, Michigan. A compression station for the gas is already in place. If the

anaerobic digester were built adjacent to the compression station the gas could be fed via an existing pipeline to the potential host. If this agreement is not amenable, West Michigan LLMPC could look for hosts with similar energy needs.

The biosolids produced by the digester will come in a semi-solid form. This material is humus-like and useful as a fertilizer replacement. It has a potential value of approximately \$35 per ton. Considering its phosphorous, potassium, and nitrogen content the digestate has a value of approximately \$90 per ton, though it is unlikely it could be sold for that high. Potential users of the digestate are agricultural producers with crop nutrient requirements, nurseries, and golf courses.

Three of the four technologies studied produced a liquid effluent from the digester. This effluent has nutrient value, but disposal of the material will be a financial burden on the centralized digester. One of the technologies studied claims it provides for treatment of the liquid effluent to meet permit regulations for disposal.

<b>Table 2: Technology Supplier Product Summary</b>				
	Waste Energy Solutions	RCM-Biothane	Andigen	Biopower Technologies
Biosolids	Yes	No	No	Yes
Liquid Effluent with Nutrients	Yes	Yes	Yes	No
Treated Wastewater	No	No	No	Yes
Commercialized Technology	Yes	Yes	Yes	No

Notes:

- Waste Energy Solutions uses solids separation to create two digestate product streams: a semi-solid and a liquid product
- RCM-Biothane's effluent is a sludge treated anaerobically but still very high in moisture (97% to 98%)
- Andigen, like RCM-Biothane, produces a liquid sludge stream. This is treated with an electro-coagulation process
- Biopower Technologies has a water treatment process that separates all nutrients into a semi-solid biosolid, leaving a treated wastewater that is suitable for disposal.

## **E. Financial Analysis**

The four vendors supplied preliminary budget estimates for the proposed anaerobic digestion facility. To complete a financial analysis FBA included estimated costs for training, engineering, and land. These cost estimates ranged from \$3.7 to \$12.4 million. This amount includes a 15% startup "contingency," that was added by FBA.

FBA believes the capital cost for a swine manure complete mix digester of this size is high. At least three of the technology providers have proprietary technology attached to their systems, requiring

royalty fees that increased the costs. One of the vendors (Biopower Technologies) has no working digester in operation. In most cases, only preliminary information was supplied by vendors.

The financial summary is shown below. The base case assumed that only swine manure was processed by the digester. Complete mix digesters are designed for 3% to 10% solids. Swine manure has relatively low solids (4% was assumed) and does not utilize the total solids capability of the complete mix digester. In general, the greater the solids entering the digester, the greater the product outputs (both biogas and biosolids), and consequently the less water that must be handled. At 4% total solids in the swine manure these systems will not be run at full efficiency, reflected in the returns on investment showed below.

<b>Table 3: Technology Supplier Summary</b>				
Annual Outputs	Waste Energy Solutions	RCM-Biothane	Andigen	Biopower Technologies
Biogas Output (m <sup>3</sup> )	6,334,649	1,780,000	1,530,000	1,430,000
Methane Volume in Biogas	156,593 mmBTU	40,850 mmBTU	36,681 mmBTU	32,798 mmBTU
Methane Revenue	\$147,176	\$136,846	\$122,880	\$109,873
Digestate Value	\$549,000	\$472,500	\$472,500	\$472,500
ROI	-11.6%	-11.3%	-5.7%	-1.1%

As indicated above, the biogas output for the Waste Energy Solutions system is more than three times that of the other digesters. The WES digester operates in the thermophilic (higher) temperature range. This system also has a higher capital cost.

From a financial standpoint, Biopower Technologies showed the best, albeit negative, return. This is primarily due to the proprietary wastewater treatment system licensed to the digester, which treats the water sufficient for it to be disposed of, a clear advantage over the other technologies reviewed for this report. However, to date this technology has not been commercialized.

## **F. Management and Business Structure**

Successful management of the digester will be a key to its continued operation. A manager should be selected who has experience in anaerobic digestion.

FBA recommends the business structure be flexible in allowing feedstock suppliers, and non-producers and non-growers to participate. The anaerobic digester should handle pickup and delivery of the swine manure from the producers to the digester. The current financial model will not allow and producers will unlikely accept a tipping fee for the handling of the manure.

## **G. Recommendations**

A centrally-located anaerobic digester for the collection of swine waste will be feasible only if the members of the venture can economically benefit from the digester, or the digester is installed to

reduce a nuisance factor, and/or the disposal of swine manure is mandated. West Michigan LLMPC will be a profitable venture if:

- Swine producers invest in the digester as a “cost of doing business” to reduce odor complaints and to comply with regulations.
- Project funding in the form of grants and other subsidies lowers the capital investment requirements for the producer investors.
- The total solids content in the manure is increased to an average of 6% to generate sufficient biogas and biosolids to see a 15% total return in investment.

FBA recommends Biopower Technologies be studied further. It is the only supplier offering a treatment of the wastewater, which reduces the volume of material handled by the digester facility and allows the safe disposal of wastewater from the digester. West Michigan LLMPC should complete the following steps before proceeding to commercialization:

1. Perform tests on local swine manure to determine the actual total solids, volatile solids, and BOD to allow better estimations of digester performance
2. Obtain compositional analysis of digestate from Biopower Technologies using regional swine manure as a feedstock.
3. Perform a market assessment to determine optimal level of biosolids allowed in the local market

## II. Scope of Work

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### A. This study is covered by the following agreement:

1. A Grant Agreement between the State of Michigan, Department of Labor & Economic Growth, and Michigan Allied Poultry Industries, Grant No. PLA-04-59, titled: *Liquid Manure to Energy Project*.

### B. Problem Statement

The West Michigan region (consisting primarily of the counties of Ottawa, Allegan, Muskegon, Kent, and Barry) has had one of the highest levels of livestock production in the state. Historically, the livestock manures produced in the region were utilized as a nutrient source for agricultural cropland producing grains, oilseeds, hay, horticulture plants, fruits, and vegetables. The application rate of these livestock manures on agricultural production acreage was not regulated until a few years ago.

Recent Federal and State EPA regulations have been put in place to regulate the amount of livestock manure that can be placed on agricultural cropland. Designated as regulations for Concentrated Animal Feeding Operations (CAFO), these regulations have been designed to limit the amount of livestock manure nutrients that can be applied to the land. The amount is limited to what can be utilized by crop production in a certain period of time. One of the primary nutrients contained in livestock manure is phosphorous (P), which has a tendency to build up in the soils, since crops cannot utilize it at the same rate as the other two primary nutrient sources, nitrogen (N) and potassium (K). This has resulted in a situation where much of the cropland in West Michigan contains such high phosphorous levels that EPA regulations are severely limiting the levels of livestock manure applications. This has caused many West Michigan livestock producers to seek other methods of utilizing their livestock manure production.

In 2002, a group of West Michigan poultry producers investigated the feasibility of converting their livestock manure (poultry litter) into other value-added products, including thermal and electricity energy. It was expected that since these products derived from a renewable biomass source—poultry litter—the products would have higher demand than products produced from non-renewable sources, i.e. fossil fuels. Seven poultry producers formed a company with the purpose of providing sufficient volumes of litter to justify a poultry litter-to-energy conversion facility. A feasibility study was undertaken by an outside agricultural processing consulting firm, Frazier, Barnes & Associates (FBA) to assist in locating and sourcing public funds for the project. The feasibility study analyzed several technologies for the conversion of the poultry litter to energy, including direct combustion, gasification, pyrolysis, and anaerobic digestion. Anaerobic digestion was found to be unsuitable due to poultry litter's relatively high solid content. Anaerobic digestion was found to be more suited for lower solid feedstocks.

This project will utilize a similar strategy as the first project, but concentrate research on analyzing the feasibility of anaerobic digestion of liquid swine manure. The West Michigan Livestock

Producers Group has asked FBA to conduct a study for liquid manure-to-energy conversion using anaerobic digestion.

The principal feedstock for the anaerobic digestion facility is swine manure. FBA did not include beef or dairy manure feedstocks and this study did not include a study of beef or dairy manure anaerobic digestion. The product outputs and economics will differ with beef/dairy over swine manure feedstock.

**Map 1: Project Study Region**



### **C. Study Scope of Work**

The Scope of Work for the project includes the following deliverables:

- A. Feedstock Availability
- B. Technology Factors
- C. Product Market Factors
- D. Financial Factors
- E. Management and Business Structure Factors
- F. Recommendations for Commercialization
- G. Written Report

### **Study Methodology:**

- A. Liquid Livestock Manure Feedstock Availability. A regional township-by-township liquid livestock manure feedstock availability analysis will be conducted in the following West Michigan counties:

- Ottawa County
- Allegan County

The survey will reveal the volume of liquid manure produced in each county and the type of liquid manure produced (swine, dairy or beef).

This information is to be provided jointly by HFB and MSUE.

- B. Technology Factors. A survey of anaerobic digestion technologies will be performed to determine all available technologies for this project. To be considered for use the technologies must meet these requirements:

1. The technology must be an anaerobic digester.
2. The anaerobic digester must not only be able to produce methane efficiently, but must either come with technologies or be adaptable to other technologies that can manufacture additional value-added products (ammonia, sulfur, compost, etc.).
3. The selected technology must be designed to handle liquid manure or feedstocks with comparable moisture as liquid manure.
4. The technology under consideration must be commercializable.

Using the above criteria, all available anaerobic digesters will be narrowed down to three using the following criteria:

1. Lowest capital costs per unit processed.
2. Lowest operating costs per unit processed.
3. Highest product yields per unit processed.
4. Highest value of products (methane, fertilizer) produced per unit processed.
5. Lowest economy of scale.
6. Highest economic return on investment which is largely determined by the five criteria above.
7. Greatest feedstock flexibility (ability to process multiple types of biomass feedstock).
8. Lowest environmental impact cost for processing plant.
9. Greatest potential electrical power yield.
10. By-product disposal/marketing costs.
11. Site requirements:
  - Proximity to existing biomass feedstock(s)
  - Utility requirements
  - Utilization of existing available infrastructure
  - Size of construction site
  - Proximity to end-users of industry

This information is to be provided by FBA.

C. Product Marketing Factors. The two primary products, methane gas and fertilizer co-product(s), will be analyzed for the following:

1. Value of methane gas to regional large natural gas consumers
2. Market access to regional large natural gas consumers
3. Value of fertilizer co-products in:
  - Regional markets
  - Markets outside of feedstock procurement region (includes transportation costs)
4. Federal and State tax credits or production credits associated with the production of “renewable” or “green” methane gas products.

This information is to be provided jointly by ZFS and MSUE.

D. Project Financial Analysis. Proforma financial projections will be provided for each of the selected anaerobic digestion conversion technologies. These proforma projections will contain:

1. Feedstock requirements and anticipated transportation costs
2. Conversion facilities operating costs (two sizes for each selected technology)
3. Capital costs (two sizes for each selected technology)
4. Methane and fertilizer product values/markets
5. Return on Investment analysis

This information is to be provided jointly by FBA and MSUE.

E. Management and Business Structure Analysis.

- Management Requirements for Liquid Manure Conversion Project
  - General Management
  - Product Sales
  - Financial Management
  - Operations Management (Plant Operators and Maintenance Workers)
- Business Structure Option Review
  - Producer-Owned (Closed Cooperative)
  - Privately Held Company
  - Closed Coop/Privately-Held Company
  - Other

This information is to be provided by FBA.

F. Project Commercialization Recommendations.

- Discussion of project commercialization steps
- Recommended conversion technology supplier and facility size
- Optimal location(s) of facilities

This information is to be provided by FBA, with input from other team members.

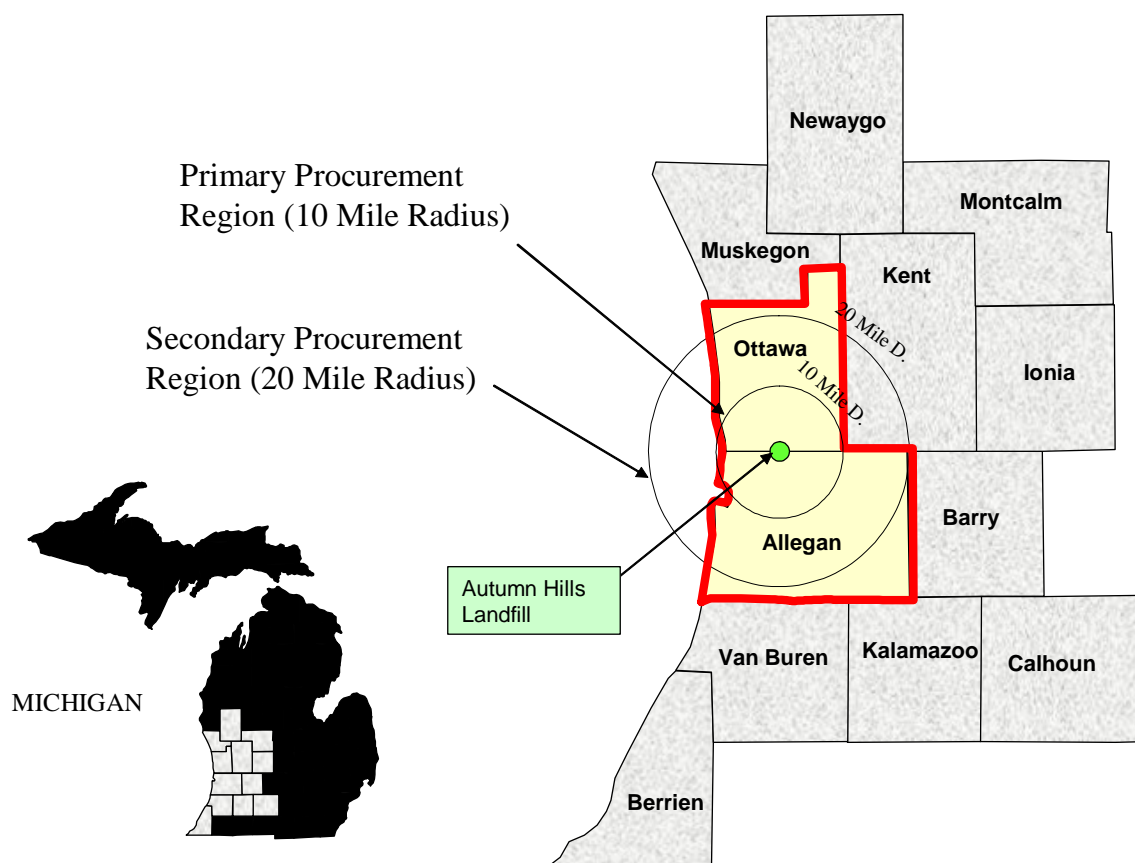
G. Written Report.

Development of a written Feasibility Study Report for the project will be provided that fully examines all of the study deliverables described in this section.

This information is to be provided by FBA, with input from other team members.

### III. Liquid Manure Feedstock Availability

**Map 2: Liquid Feedstock Procurement Region**



#### A. Producer Survey

Charles Gould, of Michigan State University Extension, conducted an extensive survey of area producers. A letter describing the project was sent to all area producers in November, 2004, along with a questionnaire. A copy of the letter is included in the Addenda. Mr. Gould followed up the written letter by visiting the majority of those producers to whom the letter was sent. All of the producers within ten miles of the proposed regional anaerobic digester were visited in person by Mr. Gould.

There were 29 survey responses, roughly two-thirds the total surveys sent out. Thirteen of the respondents have swine facilities, two respondents have both swine and dairy facilities; the remainder are dairy operations. Many of the respondents have multiple facilities: a total of 70 facilities, of which 45 were swine facilities, and 25 dairy facilities.

The two main objectives of the survey were:

1. Determine the volume of liquid swine manure in Ottawa and Allegan Counties
2. Determine the producers' level of interest in participating in a regional anaerobic digester

There were six questions. A breakdown of the questions and the responses follows.

1. Do you use any manure solids separation equipment (i.e. mechanical, gravity, etc.) on the farm?

All of the swine producer respondents answered No to this question.

2. Trucking liquid manure from your farm to a regional anaerobic digester is one transportation option that will be explored in the feasibility study. What would be your hauling preference?

Breakdown of responses:

- Seven producers would prefer to truck manure to the anaerobic digestion facility
  - Five producers would prefer if someone picked up the manure (assuming they follow an approved biosecurity protocol)
  - One producer answered that it depended on the distance to the digester
3. How frequently could shipments of at least 7,000 gallons of liquid manure be transferred from your farm to the regional anaerobic digester facility?

<b>Table 4: Survey Question 3 Response</b>	
Category	Responses
Once a day*	3
Once a week	3
Twice or more a week	1
Once/two weeks	2
Once/month	1
Every other month	0
Once/3 months	1
Once/6 months	0
Once/year	0
Other	0
No Response	1

\* One producer surveyed indicated that manure could be picked up twice a day, with an annual estimated production of 5,000,000 gallons.

The majority of the producers indicate there is sufficient feedstock to be picked up at a frequency of no more than once every two weeks.

4. For each liquid manure storage facility on your farm....

Producers were asked for:

- The name of the storage facility

- The type of livestock operation/growth stage that best describes the source of the manure
- Number of days of designed storage capacity
- Estimated annual volume of manure produced per site
- Type of bedding found in the manure
- Average percent dry matter content of the manure
- Location by township and county

A summary of responses to this question:

- Manure is stored an average of 200 days (three finish operations had storage of 30 days; these were considered outlier data and excluded from the average calculation)
- The total annual manure handled by the respondents was approximately 41 million gallons a year. This includes only those producers who responded to the survey (2/3 of the total in the region), so the available number is expected to be in the range of approximately 62,500,000 gallons a year.
- Each farm facility handles an average annual volume of 916,000 gallons a year
- The average dry solids content of the liquid swine manure is 5%
- Eighteen of the swine facilities use straw bedding material; the other swine facilities do not use bedding.
- A breakdown of the types of operations:

<b>Table 5: Survey Question 4 Summary</b>		
Type of Operation	Facilities	%
Farrowing	5	11%
Farrow-Finish	14	31%
Nursery	6	13%
Breeding-Gestate	2	5%
Grow-Finish	18	40%
<i>Total Facilities</i>	45	100%

5. Would you be willing to provide Michigan State University Extension with a copy of a manure analysis for each storage structure listed in Question 4 for use as baseline data?

There were 13 responses:

- 7 producers indicate they do not have a manure analysis
- 5 producers answered Yes
- 1 producers answered No

6. Would you be interested in investing in a regional anaerobic digester?

- 10 answered Yes (77%)

- 2 answered No (15%)
- 1 was undecided (8%)

For those respondents that answered No to this question, the main reason for this response was the producers felt they had sufficient land base and did not want to give away their nutrients.

## **B. Available Feedstocks**

Although swine manure is the primary feedstock to be utilized by the anaerobic digester, a summary of other feedstocks is included in this study. It may be necessary to mix secondary feedstocks in with the swine manure to optimize a digester's methane and co-product output.

### Swine Manure

There is approximately 41 million gallons of swine manure available within 20 miles of the Autumn Hills Landfill (based on reported numbers by the survey respondents)<sup>1</sup>.

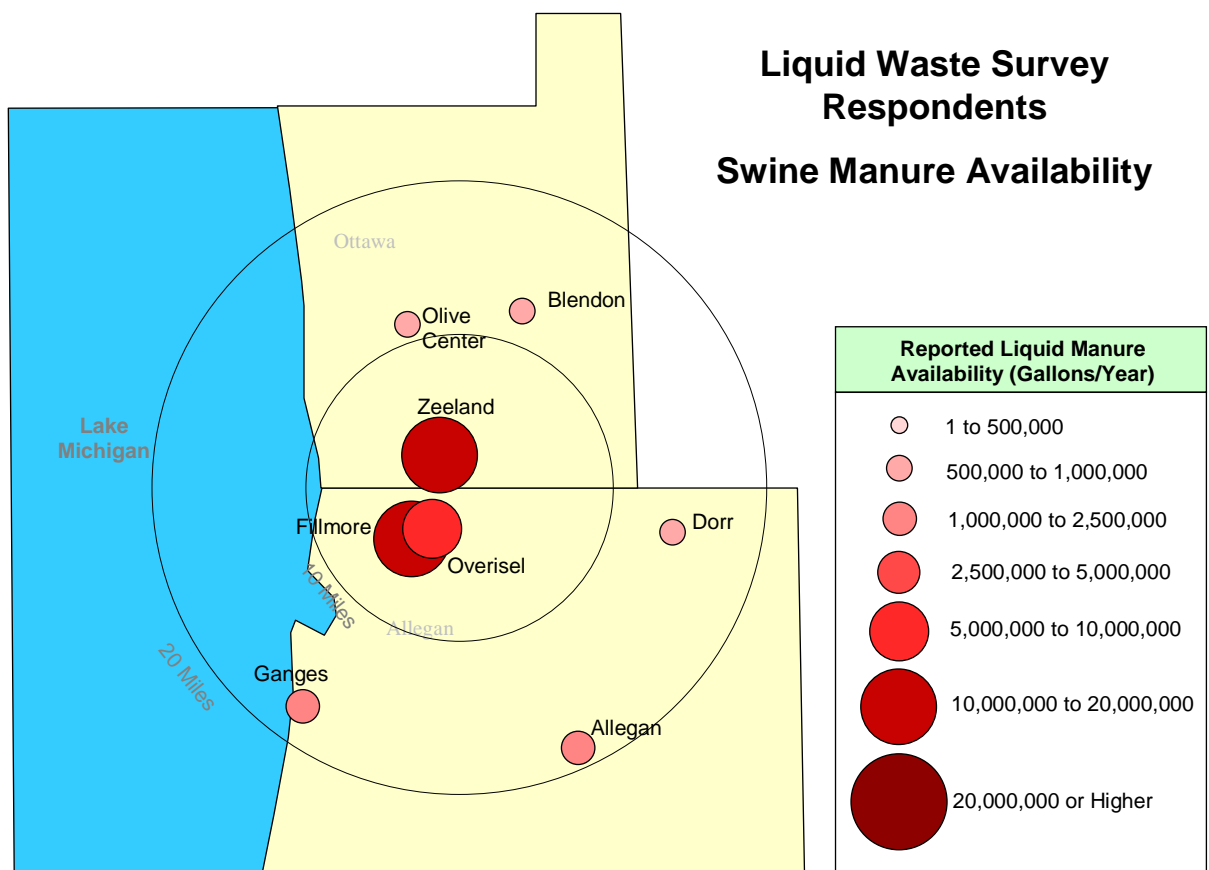
<b>Table 6: Swine Manure Availability Within 20 Miles</b>		
<b>Township</b>	<b>Manure (Gallons/Year)</b>	<b>Structures (Facilities)</b>
Allegan and Ganges	3,231,000	2
Blendon	780,000	3
Dorr	580,000	2
Fillmore	17,723,939	11
Olive	550,000	5
Overisel	5,855,238	10
Zeeland	12,206,550	8
<i>TOTAL</i>	40,926,727	41

The three largest sources of swine manure are within 10 miles of the potential digester facility and combined produce 35.8 million gallons per year, or approximately 88% of all swine manure in the 20-mile procurement region. This quantity is sufficient to meet the demand of a 100,000 gallon per day facility for 350 days per year.

<b>Table 7: Swine Manure Availability Within 10 Miles</b>		
<b>Township</b>	<b>Waste (Gallons/Year)</b>	<b>Structures (Facilities)</b>
Fillmore	17,723,939	11
Overisel	5,855,238	10
Zeeland	12,206,550	8
<i>TOTAL</i>	35,785,727	29

<sup>1</sup> Gould, Charles. Michigan State University Extension.

The map below shows swine manure concentrations in the region.

**Map 3: Swine Manure Availability for Allegan and Ottawa Counties**

### Mortality

Mortality is a potentially rich source of methane gas. Mortality is a term for carcasses of dead animals that result as a normal part of animal feeding operations (AFO). Carcasses are normally disposed of at an added expense to an AFO. Ottawa and Allegan Counties in Michigan have a large number of mortality from various livestock operations. A survey conducted by MSU and HFB concluded there is approximately 1,425,000 lbs a year of swine mortality available (713 tons a year, or approximately two tons per day) in Allegan and Ottawa Counties.

Ottawa County also had 1,067 deer killed in 2004. The County has a contract with a local vendor to pick up deer carcasses and dispose of them in the local landfill. It is estimated that Allegan County has a comparable number of mortality, giving approximately 2,000 deer carcasses on an annual basis in the region. Fawns average 100 pounds; does 140 pounds; bucks 160 pounds<sup>2</sup>. No data is available on the distribution of how many fawn, doe or buck carcasses are available. It is assumed the average weight of a carcass is 140 pounds. This gives approximately 140 tons per year of deer carcasses in Ottawa and Allegan counties.

<sup>2</sup> Pennsylvania State University, Department of Animal Science and the Pennsylvania Game Commission, 1968

### Offal

Offal are the waste parts of butchered animals<sup>3</sup>. There are a number of slaughtering facilities within proximity of the project Study Region, including:

- Packerland; Plainwell, Michigan (Cattle slaughter) (30 miles)
- Darling International; Detroit, Michigan (Rendering plant) (130 miles)
- Darling International; Coldwater, Michigan (Rendering plant) (80 miles)
- Kruger Commodities, Inc.; Hamilton, MI (Rendering plant) (10 miles)

Michigan Turkey Producers in Wyoming, Michigan produces approximately 450 tons of offal per week, along with the following additional slaughter wastes:

- 190,000 lbs of feathers per week
- 92,600 lbs of blood per week

This equates to approximately 30,000 tons a year of slaughtering waste and offal. When contacted, the manager of this facility indicated there would be interest in possibly transporting the offal to a Michigan-based anaerobic digester. However, the offal provides MTP a revenue stream and could not be delivered at zero cost. MTP would be willing to have the blood removed at no cost, however. This facility is approximately 15 miles from the proposed anaerobic digestion facility location.

According to Kevin Kirk, Michigan Department of Agriculture, the law in Michigan does not recognize the use of offal or mortality in any disposal method other than that recorded by law; i.e., anaerobic digestion is not written into the law. Researchers from Michigan State University are trying to broaden the scope of products that may be disposed of in anaerobic digesters in Michigan. Though offal and mortality cannot currently be utilized in anaerobic digesters in Michigan, FBA will still examine their use in the event mortality disposal laws change in the state, as mortality and offal are low (or no) cost feedstocks.

### Food Wastes

Food wastes are a high-moisture content by-product of the food processing industry. One potential source is the Grand Valley State University, which generates from 200 to 250 pounds of cafeteria waste per day (approximately 36 to 45 tons per year).

FBA spoke with Don Scholten, of Bareman Dairy. Bareman Dairy discharges 60,000 to 75,000 gallons per day of rinsed milk waste with 99% moisture content. Mr. Scholten indicated that if the milk waste were not rinsed, there would be 3,000 to 4,000 gallons a day of 9% solids material available. This is 1,050,000 to 1,400,000 gallons a year. Bareman would consider an arrangement with the digester at a future date once the project is closer to commercialization. This would likely require a fee paid to the dairy, according to Mr. Scholten, though he explained it was too early to determine what that fee would be.

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<sup>3</sup> American Heritage Dictionary of the English Language. 4<sup>th</sup> Edition. 2000.

### Corn Stover

Corn stover is the stalks and other biomass remnants that remain after a harvest of corn. For each bushel of corn harvested an approximately equal amount of stover is produced. Producers normally leave the stover on the field as part of normal crop husbandry for nutrient applications. However, only a portion of the stover is required for this purpose. Although individual farm needs vary, FBA estimates that 50% of the stover is required; the rest could potentially be collected, densified and transported for off-farm use, such as in the proposed anaerobic digester.

<b>Table 8: Corn Stover Availability</b>			
County	Corn Production	Stover Available (Bu.) (@ 50%)	Stover Available (tons)
Allegan	10,550,000 Bu.	5,275,000 Bu.	147,700 Tons
Ottawa	4,300,000 Bu.	2,150,000 Bu.	60,200 Tons

Note: 1 Bushel of corn = 56 pounds.

These two counties combined have approximately 207,900 tons of corn stover available on an annual basis. Corn stover is relatively low in moisture content (35% to 40%) so a minimal amount is needed to elevate the solids content of the digester influent stream.

Estimates for corn stover place its value at \$30 to \$35 per ton, delivered out to 50 miles. This is a combination of the producer payment, the cost of baling, and hauling costs. The collection of corn stover remains one of the major hurdles to its use as a wide-scale feedstock. Custom harvesting and other equipment may be required. Purdue University lists the following equipment as a potential requirement for a successful stover harvesting operation<sup>4</sup>:

- Combination flail chopper/windrow to prepare for baling
- A baler to bale the stover into bales (approximately 1 ton bales). A quote of \$50,000 for this equipment was indicated in Purdue's report.
- Flatbed trailers to haul the bales

Purdue's report indicates a cost associated with the collection and transportation of the corn stover at \$14 to \$22 per ton. This puts the usability of corn stover as a feedstock for a digester in question. FBA believes the infrastructure for collection of stover is immature in West Michigan and requires further development to reduce the costs of collection. The current capital costs for specialized handling equipment for the collection of stover make it infeasible. Corn stover will not be considered in this study.

### Corn Silage

Corn silage has approximately 30% total solids, so it cannot be the principal feedstock for anaerobic digester, but it could be a potent source of biogas as a supplementary feedstock. Biopower Technologies, for example, tested silage in its anaerobic digester and estimated it produces 177 m<sup>3</sup> of biogas per ton (compared to 10 m<sup>3</sup> of biogas per equivalent ton of swine

<sup>4</sup> Nielsen, R.L. Dr. (1995). Agronomy Department, Purdue University. Questions Relative to Harvesting & Storing Corn Stover. AGRY-95-09.

manure at 4% total solids). Price of the silage and its year-round availability are two of the issues for use in digesters.

<b>Table 9: Corn Silage Availability</b>				
County	Corn Silage 2003	Corn Silage 2004	Corn Silage 2005	3-Year Average
Allegan	130,000 Tons	315,000 Tons	225,000 Tons	223,330 Tons
Ottawa	<u>145,000 Tons</u>	<u>155,000 Tons</u>	<u>110,000 Tons</u>	<u>136,670 Tons</u>
Average	275,000 Tons	470,000 Tons	335,000 Tons	360,000 Tons

At 9 lbs per gallon, there are approximately 80 million equivalent gallons of corn silage available on an annual basis in Allegan and Ottawa counties (228,500 gallons/day).

Pricing mechanisms exist for estimating the value of corn silage. MSU Extension, for example, has a formula based on the price of corn for grain. At \$2.00 per bushel for corn they value corn silage at \$18 per ton<sup>5</sup>. At \$18 per ton, the per gallon equivalent cost of corn silage would be \$0.08. At this rate, there would be an approximately *negative* 100% return on investment. Corn silage would be viable only if it could be obtained at zero cost to the digester.

#### Yard Debris

There is approximately 33,800 tons a year of yard debris (grass clippings, brush, and leaves) available in the two-county study region<sup>6</sup>:

<b>Table 10: Available Yard Debris</b>				
	Grass	Brush	Leaves	Total
10-Mile Radius*	3,025	3,025	4,033	10,083
Ottawa and Allegan Counties	10,150	10,150	13,534	33,834

\* 10-Mile radius from Autumn Hills Landfill, in Ottawa County

The primary concern with using yard debris in a digester is the potential contamination due to chemicals or other materials (such as plastic) in the debris.

#### Yellow Grease

Yellow grease, one of the by-products of the rendering industry, is a high source of the volatile solids needed for methane generation at a digester. However, given the increased use of biodiesel and the growth of the biodiesel industry, yellow grease has become in greater demand.

Fats and oils that can be used in biodiesel production can come from a variety of plant and animal sources. Because of this cost and complexity issue, many existing biodiesel manufacturers choose to produce biodiesel from as few types of feedstock as possible. Generally, biodiesel can be produced from any of the following types of feedstocks.

<sup>5</sup> Pennington, D. Michigan State University Extension. Ag Facts: Forage Contracting and Dairy Operations.

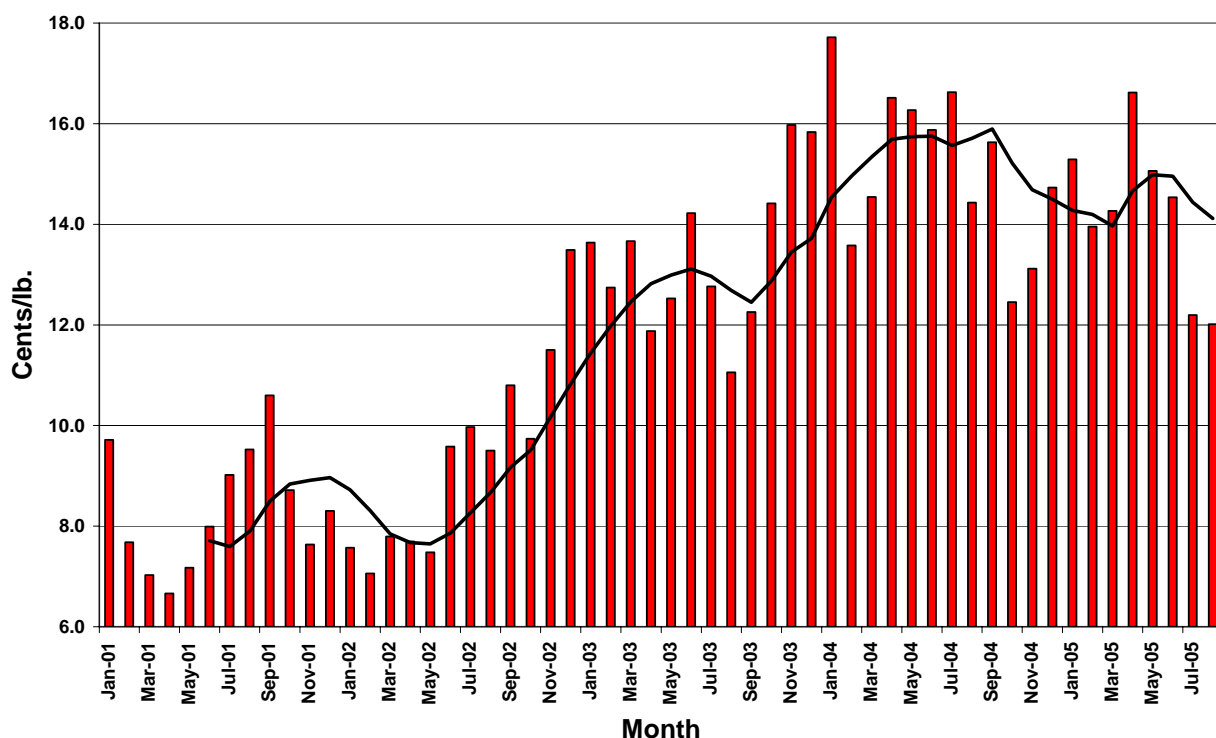
<sup>6</sup> Gould, Charles. Michigan State University Extension.

- Virgin Vegetable Oil – Soybean, Canola, Rapeseed, Corn, Sunflower, etc.
- Waste Vegetable Oil – Used oil collected from restaurants (Yellow Grease)
- Rendered Animal Fats –Beef Tallow, Pork Fats, Fish oil or Poultry fats

While the expectation is that Yellow Grease prices should remain in the seasonal ranges, two caveats do exist which have the potential to significantly alter the future outlook for animal fat prices. First, as U.S. biodiesel production increases, the inherent demand for animal fat as a feedstock, specifically Yellow Grease, will rise. Particularly with the impact of the government subsidy of \$1.00 per gallon of biodiesel produced employing “first-use“ fats, the whole picture of prices and price spreads versus vegetable oils may be dramatically changed. Secondly, as Natural Gas prices experience greater volatility, the greater the tendency for renderers and packers to utilize Yellow Grease as a substitute energy source displacing high priced Natural Gas. Either one of these scenarios will ultimately push the seasonal and absolute highs for Yellow Grease prices into new ranges.

The historical price for yellow grease has doubled from \$0.06 a pound in 2001, to \$0.12 in 2005 (\$120 to \$240 a ton). This feedstock would be unsuitable for the digester because of its high cost to the facility of \$120 to \$240 a ton. These are not low-cost feedstocks for a digester and are, as the Financial Analysis will indicate, clearly cost prohibitive. For this reason yellow grease will not be considered a viable feedstock for this project.

**Chart 1: Illinois Yellow Grease, Historical**



### Rendered Fats

Rendering plants provide traditional sources of animal fats. With the advent of spent restaurant grease, rendering plants and fat blenders have been formulating blended fat products in order to meet the demands of the animal feed manufacturing sector. In some regions of the country, it is possible to source truckloads of straight spent restaurant grease. The rendered fats industry is experiencing a similar surge in price activity. In the Mid-South, for example, poultry fat was valued in January 2001 at \$0.11 per pound; this increased to over \$0.15 per pound in July 2005. This is a value of \$220 to \$300 per ton for poultry fat.

Given no specific type of centralized futures and/or cash market, animal fat is traded mostly on a spot or weekly basis. Packers, renderers, blenders, and brokers all have the ability to source and trade specific fats, but are usually tied to specific customers that have been developed over time. Some players may offer forward contracting, but this practice is not found to be widespread nor is the contracting done much beyond a few weeks in the future.

Basis the high price of animal fats, they are not a feasible feedstock for the digester facility.

### **C. Feedstock Characteristics**

The components of feedstock pertinent to this project are the total solids content, volatile solids content, and nutrient content.

Total solids content are important in the determination of the remnant after digestion, the so-called “digestate.” The total solids are comprised of various nutrients and form the bulk of the dry matter found in the untreated material that comes out of the digester after the anaerobic digester has broken the material down to extract *biogas*. Biogas is comprised of methane (2/3) and carbon dioxide (1/3), and trace elements such as hydrogen sulfide (H<sub>2</sub>S).

Volatile solids are the “organic” component of the total solids<sup>7</sup>. Volatile solids are the principal source of the biogas from which the methane is derived. The higher the volatile solids portion of the total solids, the higher the methane generation.

### Swine Feedstock Assumptions

A grow-finish pig weighing 150 lbs will, on average, produce 1.2 gallons of manure per day as excreted, and 0.9 gallons per day in deep-pit buildings. The longer manure is stored in deep pits, the less the quality of the manure as the breakdown of volatile solids starts upon excretion. This is critical: the manure should get to the digester as quickly as possible. There will be some loss of methane due to transportation and storage prior to injection into the digester. Also, the variation in farming practices means that some producers will store the manure for different periods of time before it is delivered to the facility.

Due to the considerable variations possible from every source of swine manure, FBA made the following assumptions for this Feasibility Study:

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<sup>7</sup> AgStar Handbook, Second Edition. Glossary.

- The density of swine manure is slightly higher than water due to the presence of solids. FBA used 9 lbs per gallon; the key impact of the manure density is the effect on methane generation and on digestate solids content, and consequently, the volume of digestate generated.
- The Total Solids (TS) content of swine manure is 4% by weight (0.36 pounds/gallon)<sup>8</sup>
- The Volatile Solids (VS) content of swine manure is 2% by weight (0.18 pounds/gallon)<sup>9</sup>; the percentage of total solids is assumed to be 50% of total solids.

The quantity of biogas generated per gallon of swine manure varies with the technology utilized in its production. The bacteria in each digester operate at different temperature ranges and each technology has a different efficiency which translates into varying capital and operating costs. FBA obtained quotations from four anaerobic digester technology suppliers. These suppliers claimed 10 to 35 m<sup>3</sup> of biogas produced per ton of swine manure (one ton of manure is approximately 220 gallons).

#### Other Feedstock Assumptions

The assumptions on mortality and offal were provided by Biopower Technologies, one of the technology suppliers contacted for this report. Biopower Technologies has tested these specific feedstocks in their digester. The other technology suppliers were either unable or unwilling to reveal the methane yield of mortality or offal through their digesters. It should be noted that Biopower Technologies' digester produced the lowest yield of methane from swine manure of the four technologies researched for this study; it is possible that the methane yields shown below for mortality and offal will be higher in the three other technologies (WES, RCM-Biothane, Andigen).

<b>Table 11: Feedstock Assumptions Summary</b>				
	<b>Density (lbs/equivalent gallon)</b>	<b>Total Solids (TS)</b>	<b>Volatile Solids (VS)</b>	<b>Methane Production (m<sup>3</sup>/ton)</b>
Swine Manure	9.0	4%	2%	Varies (10 – 35)
Swine Mortality	9.0	35%	18%	258
Deer Mortality	9.0	35%	18%	258
Turkey Offal	9.0	35%	18%	215

<sup>8</sup> MWPS (2000). Manure Characteristics, MWPS-18, Section 1. Manure Management Systems Series. Iowa State University.

<sup>9</sup> Ibid.

## IV. Anaerobic Digestion Facility Technical Evaluation

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Anaerobic digestion is the breakdown of animal or vegetable matter in the absence of oxygen to produce biogas, which can be sold to a host as a replacement for natural gas. The organisms in anaerobic digesters that create the biogas are methanogenic, referring to their sensitivity to changes in oxygen, temperature, pH, and nitrates<sup>10</sup>. In general methanogenic organisms perform better in higher temperature environments.

Anaerobic digestion occurs naturally or in a controlled environment such as a biogas plant. Organic waste and bacteria is placed in an airtight container, the digester, where the process of anaerobic digestion occurs in three stages:

1. Matter decomposes into molecule-sized particles. Microbial breakdown typically heats the matter to 95°F to 100°F.
2. Particulate matter is converted into organic acids.
3. The acids are converted to biogas.

The quantity of biogas produced varies based on the operating temperature ranges of the anaerobic digester. Although anaerobic digestion can occur at *psychrophilic* temperatures (less than 68°F)<sup>11</sup>, typical anaerobic digester systems are designed for *mesophilic* (approximately 68° to 113°F) and *thermophilic* (approximately 113°F to 167°F)<sup>12</sup> temperatures because these higher temperatures shorten the hydraulic retention time (HRT) in the digester and help reduce pathogens associated with odors.

The principal products of anaerobic digestion are the biogas, and digestate. Biogas produced through anaerobic digestion is composed principally of methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>); the methane content of biogas varies from 50% or higher, depending on the equipment used. Digestate is a mixture of wastewater and solid matter (mostly non-volatile solids). The digestate varies in consistency since the operating conditions for each digester will vary and the process used in the digestate production varies with each technology.

Digestion removes most pathogens in the digestate (90%+); if near 100% pathogen removal is desired additional post-treatment will be necessary.

### Digester Technology Overview

There are three types of Anaerobic Digesters systems recognized by the USDA Natural Resource Conservation Service:

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<sup>10</sup> Steele, K., Ed. (1995). Animal Waste and the Land-Water Interface. Lewis Publishers. New York.

<sup>11</sup> (2000). BiogasWorks. An Introduction to Anaerobic Digestion.

<sup>12</sup> Metcalf & Eddy, Inc. (1972). Wastewater Engineering; Collection, Treatment, Disposal. McGraw-Hill.

Covered Lagoon<sup>13</sup>. *Covered lagoons* consist of a pit filled with biomass and sealed with an impermeable cover. As the material breaks down due to microbial activity, biogas collects under the impermeable cover and is extracted by a suction pipe. Covered lagoons are often used in dairy and swine operations that incorporate some type of flush system for waste removal, since these manures are high in moisture contents. A covered lagoon is suited for manure with 3% or less total solids, and more appropriate for warmer climates since biogas generation in lagoons is seasonal. The HRT for lagoons is longer than other types of digesters, and can be up to 60 days or more. The main advantage of covered lagoons over plug-flow and complete mix digesters is the simplicity of design and reduced operating expenses. However, a lagoon's biogas generation varies with the external temperature; there are groundwater contamination concerns with lagoon construction; and the startup of a lagoon can require up to two years before it reaches a peak capacity for biogas generation.



Covered Lagoon (Source: UIUC)

Plug-Flow Digester<sup>14</sup>. In a *plug-flow digester* biomass is collected, mixed with water to aid in a constant consistency, and fed to the sealed digester. The manure decomposes as it passes through the digester over its HRT and biogas is collected by piping. The “plug” refers to adding manure at one end of the digester and as the plug of manure cycles through the digester along a set path a new plug is added to take its place. Waste heat from the plug-flow digester can be used to heat the digester to improve its efficiency. Unlike covered lagoons, plug-flow digesters can be used in any climate because of this internal heating. However, plug-flow digesters require feedstocks with a total solids content of 11% to 13% and are unsuited to liquid manures; they are often used for dairy operations. Most plug-flow digesters operate in the mesophilic (medium) temperature range and have a HRT from 20 to 30 days.



Plug-Flow Digester (Source: RCM)

<sup>13</sup> The AgStar Program. Documents, Tools & Resources. Covered Anaerobic Lagoon (Code No. 360). [http://www.epa.gov/agstar/resources/covered\\_lagoon.html](http://www.epa.gov/agstar/resources/covered_lagoon.html)

<sup>14</sup> The AgStar Program. Documents, Tools & Resources. Plug Flow Digester (Code No. 363i). [http://www.epa.gov/agstar/resources/stand\\_plug.html](http://www.epa.gov/agstar/resources/stand_plug.html)

Complete Mix Digester<sup>15</sup>. *Complete mix digesters* are above-ground tanks built of steel or concrete. The complete mix digester is heated when necessary to provide a consistent temperature for the materials. A complete mix digester can handle feedstock with 3% to 10% total solids. The manure is agitated to keep these solids in suspension. The hydraulic retention time for complete mix digesters is typically 10 to 20 days. Biogas is collected at the top of the digester. Like plug-flow digesters, complete mix digesters can operate in any climate. There are several types of Complete Mix Digesters, including: complete stirred tank reactors (CSTR), upflow anaerobic sludge blanket (UASB), completely mixed flow reactors (CMF), and continuous flow stirred tank (CFST). Complete mix systems are more complex and expensive than plug flow and lagoon digesters.

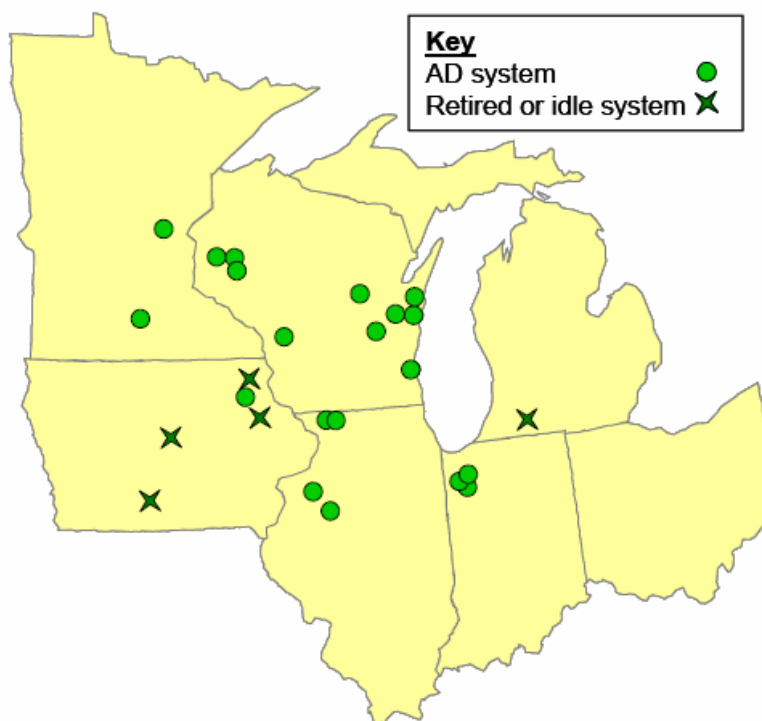
<b>Table 12: Summary of USDA NRCS-Approved Digesters</b>						
	<b>Total Solids Range of Influent</b>	<b>Operating Temperature</b>	<b>Manure Type Handled</b>	<b>Is System Heated</b>	<b>Can Handle Swine Manure?</b>	<b>HRT (Retention Time)</b>
Lagoon	< 3%	Psychrophilic	Flushed	No	Yes	60 days
<b>Complete Mix</b>	<b>3% to 10%</b>	<b>Mesophilic or Thermophilic</b>	<b>Scraped or Flushed</b>	<b>Yes</b>	<b>Yes</b>	<b>10 to 20 days</b>
Plug Flow	11% to 13%	Mesophilic	Scraped	Yes	No (dairy only)	20 to 30 days

The technology selected for study in this report is the Complete Mix Digester. The complete mix can handle swine manure with a total solids content of approximately 3% to 10%.

A resource called the *Agricultural Biogas Casebook* profiled and studied existing on-farm digesters in the Midwest region and those under construction, as of 2004. The casebook described several anaerobic digesters and the problems they encountered during operation, gathered with information obtained from interviews. A map of these on-farm digesters is shown below.

### **Map 2: Midwest On-Farm Digesters**

<sup>15</sup> The AgStar Program. Documents, Tools & Resources. [Complete Mix Digester \(Code No. 364i\).](http://www.epa.gov/agstar/resources/stand_plug.html)  
[http://www.epa.gov/agstar/resources/stand\\_plug.html](http://www.epa.gov/agstar/resources/stand_plug.html)



Source: Agricultural Biogas Casebook (2004)

The retired Michigan digester (Fairgrove Farms, Sturgis, Michigan) was a plug-flow system that ended its dairy operation in 2002. The on-farm system cost \$200,000 at the time of installation (1981) and served 700 cows. This dairy plug-flow digester produced about 500,000 m<sup>3</sup> of biogas a year (about 30,000 mmBTU/year) and also generated electricity to offset the farm's energy bill<sup>16</sup>.

Of the 20 existing/under construction anaerobic digesters in this region, 18 were dairy, 1 was for swine, and 1 for ducks. The swine operation is Apex Pork, located in Illinois, an 8,300 swine finishing operation. This is a heated mixed covered lagoon. Only 3 of the dairy digesters were complete mix; the duck farm was operating a complex mix as well. The total cost for the duck farm complete mix was approximately \$161 per AU (1 AU is roughly equivalent to 1,000 lb of animal weight). FBA refers the reader to the Agricultural Biogas Casebook for additional details.

AgStar maintains a database of operational anaerobic digesters<sup>17</sup>. Forty one digesters are listed, ten of which are swine digesters. The swine digesters are listed below:

<b>Table 13: Operating Swine Digesters in the U.S.</b>				
<b>State</b>	<b>Year Built</b>	<b>Animal Type &amp; Population</b>	<b>Manure Handling</b>	<b>Installed Cost</b>
CA	1982	300 sows; farrow to finish	Flush	\$220,000
CO	1999	5000 sow farrow to wean;	Pull plug	\$368,000

<sup>16</sup> Biogas Energy Systems, A Great Lakes Casebook. Great Lakes Regional Biomass Energy Program. Prepared by J.K. Cliburn & Associates. May 1993.

<sup>17</sup> Guide to Operational Systems. AgStar. <http://www.epa.gov/agstar/operation/bystate.html>

		1200 growing pigs		
IL	1998	8,300 finishing hogs	Pull plug	\$140,000
IA	1998	3,000 nursery pigs	Pull plug	\$15,000
IA	1996	5,000 sow farrow to wean	Pull plug	\$500,000
MS	1998	145 pigs	Recycle flush	\$27,000
NC	1997	4,000 sow farrow to wean	Pull plug and gravity	\$290,000
PA	1985	4,000 (type unknown)	Scrape	\$225,000
PA	1985	1,000 sow farrow to finish	Scrape	\$325,000
VA	1993	600 sow farrow to feeder	Flush and pull plug	\$85,000

Source: AgStar

These digesters are for on-farm application and much smaller than the proposed centralized digester. The information is useful to illustrate the variability in cost associated with similar systems. For example, the farrow-to-wean digesters have from 4,000 to 5,000 pigs but vary from \$290,000 to \$500,000 in cost.

FBA contacted five suppliers of complete mix anaerobic digesters capable of handling the swine manure in West Michigan, described below. FBA is not recommending a particular technology supplier at this time. The vendors outlined below were each contacted by FBA, interviewed, and information requested. The information that follows is to be considered preliminary budget estimates only. No estimates were provided for utility work for connections to water, power or gas; or for required permits. All technology suppliers were asked to provide estimates for a digester generating biogas only; no systems include the cost of electricity generation. All suppliers offer process guarantees.

#### **A. Waste Energy Solutions**

Waste Energy Solutions, LLC (WES) has partnered with NIRAS, a Danish company, to develop anaerobic digestion systems for development in the United States markets utilizing the NIRAS technology. WES is based in the United States and offers turnkey projects.

WES digesters can operate in both mesophilic and thermophilic temperature ranges. Given the size of this proposed facility, WES selected a thermophilic digester. Although the thermophilic digester produces a significantly greater volume of biogas than the mesophilic digester, this increased volume of biogas comes at a higher capital cost.

The contact information for Waste Energy Solutions:

Steve Dominick, Regional Director  
Waste Energy Solutions, LLC  
205 McKnight Park Drive  
Pittsburgh, Pennsylvania 15237  
Ph: (412) 364-1281

[www.fromwastetoenergy.com](http://www.fromwastetoenergy.com)

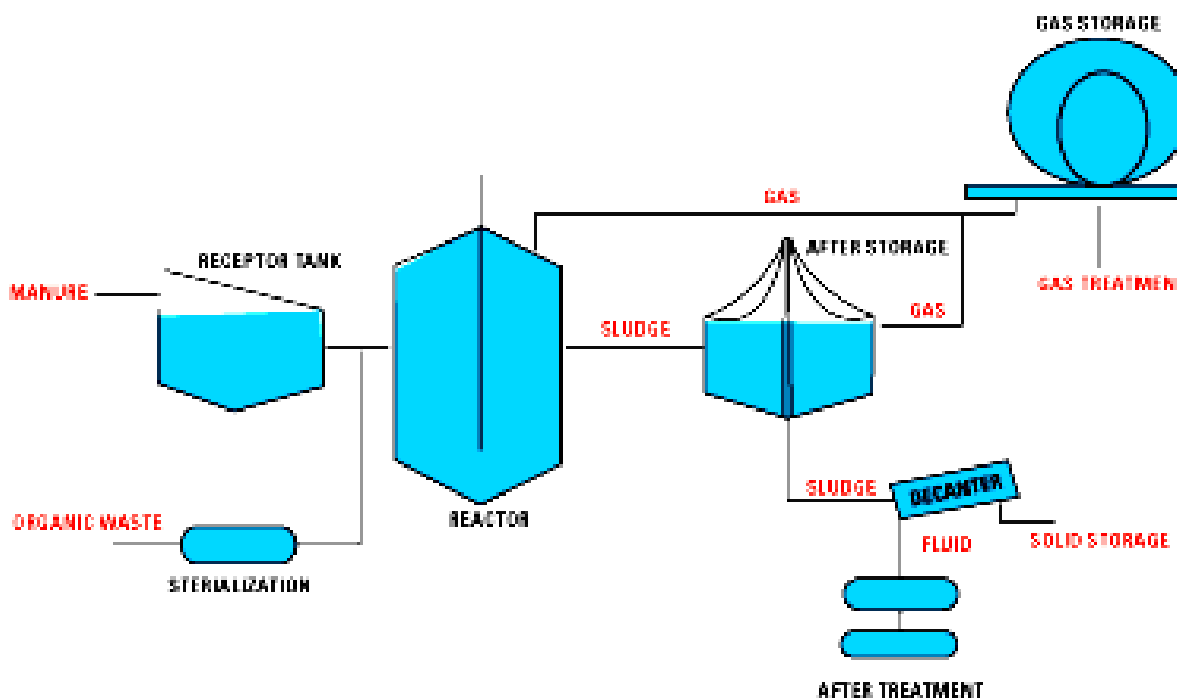
The WES process involves three major steps:

1. The feedstock (swine manure) and acid-forming bacteria are introduced into the digester. The bacteria form simple organic acids that begin the process of breaking down the feedstock into molecular components.
2. Simple organic acids and methane-forming bacteria are introduced to the digester. This combination works to produce the biogas.
3. Biogas is collected from the digester.

The WES Process in more detail:

- Swine manure is delivered to the facility through a Reception Hall.
- Feedstocks are ground up, if necessary, to reduce the particle size and held in smaller tanks. A grinder is used if a higher quality feedstock with a greater solids concentration than swine manure is added to the influent stream.
- Feedstocks are put through a Hygienic Process to remove pathogens.
- Waste products are combined from different tanks at the Reception Hall and processed into the Pre-Storage Tank for mixing at proper levels and ratios.
- The mix is injected from the Pre-Storage Tank to the Digester Tanks by an automated system.
- After a 14-day hydraulic retention time the product is sent to the After-Storage Tank, where it spends 7 days de-gassing (this is where the biogas is produced).
- Biogas is collected in the Gas Holder Tank.
- The digestate is pumped to a solids separator, a centrifuge which yields a solid dry matter and a separated liquid.

### **Chart 2: WES Process Flow Diagram**



Source: Waste Energy Solutions

The WES system described requires four or five employees to operate. The capital costs includes operator training. Required personnel include a Plant Operator, truck drivers, and plant maintenance. WES claims the plant can be operated efficiently one shift per day on a five-day work week; the balance of the week the process can be operated in automated mode with a remote monitoring system that handles the 24/7 monitoring of the process.

WES noted that the Carbon/Nitrogen (C/N) Ratio of swine manure is very low and for the WES digester to operate efficiently, some material would need to be supplemented with the feedstock mix. FBA had initially used an approach of obtaining quotations from all vendors assuming a Base Case of 100% swine manure only. The WES digester would not operate as efficiently without some type of material to increase solids and carbon content. Therefore, the following assumptions were made in this quotation:

- The feedstock is a mixture of swine manure and turkey offal
- 17,500 tons a year of turkey offal (50 tons/day)
- 140,000 tons a year of swine manure (approximately 88,900 gallons/day)

This mix was optimized to provide 7.4% total solids content and to provide sufficient carbon into the mix to aid in the efficiency of the digester.

#### Product Values

The WES digester produces 12.44 m<sup>3</sup> of biogas per ton of swine manure and 299.5 m<sup>3</sup> biogas per ton of turkey offal. The WES digester, operating at 100,000 gallons per day, would generate 6,334,649 m<sup>3</sup> of biogas per year. This digester operates in the thermophilic temperature range; WES

rates the biogas having 75% methane content. This equates to 156,593 million British thermal units (mmBTU) per year. The value of the methane produced will be discussed in the Financial Analysis section of the report.

This WES digester configuration produces two co-products: a semi-solid material suitable for bedding or potting; and a liquid component useful as a replacement fertilizer. WES estimates the value of the solid dry matter from the treated digestate at \$20 per ton, and the quantity at 10,500 tons per year produced by the digester. The replacement fertilizer volume equates to enough for 11,300 acres per year at \$30/acre (this number was provided by WES, not by FBA—an analysis of digestate value as a fertilizer replacement will be discussed further in the report).

The disposal of offal and mortality through anaerobic digestion is not recognized by Michigan law. Because of this, on March 16 of 2006 WES withdrew from the project citing concerns over the feedstock mix. To quote Steve Dominick, Regional Director for Waste Energy Solutions:

“Waste Energy Solutions decided not to pursue this opportunity because there did not seem any opportunity to build the design so that it could one day potentially operate thermophilically with the right waste mix.”

FBA is providing all information given by WES and will still analyze the digester technology and its financial returns. The capital costs, operating costs and the outputs from the WES anaerobic digestion process are shown in the following tables.

<b>Table 14: Waste Energy Solutions Anaerobic Digestion Facility 100,000 Gallons Per Day</b>	
	<b>Capital Cost</b>
Equipment (Digester)	\$7,000,000
Water Treatment	\$818,750
Engineering	\$740,000
Site Preparation	\$780,000
Buildings	\$575,000
Startup Costs	\$575,000
Other (Royalty, Misc.)	\$262,000
Land	\$100,000
Contingency (15%)	<u>\$1,627,613</u>
<b>Total Installed Cost</b>	<b>\$12,478,363</b>

<b>Table 15: Anaerobic Digester Revenue Outputs Using Swine manure and turkey offal influent mix</b>	
<b>Revenue Category</b>	<b>Output</b>
Biogas (per year)	6,334,649 m <sup>3</sup>
Methane Gas Available (mmBTU/year)	156,593
Liquid Replacement Fertilizer (acres/year)	11,300
Solid Bedding and Potting Material (tons/year)	10,500

**Environmental Impact:**

Anaerobic digesters are inherently non-environmental impacting technologies: the breakdown of the feedstock helps to reduce the odors. There is no combustion of materials and thus no spreading of chemicals to the atmosphere. The most common problems associated with anaerobic digesters are the water required to slurry the feedstock to the proper concentration for the biological process to be efficient; and the subsequent wastewater treatment system required meet discharge permit limits set by the EPA. The annual operating costs include the cost for environmental compliance.

**Feedstock Flexibility**

Most anaerobic digestion systems use biological processes, which generate particular types of organisms, making the technology sensitive to changes in feedstock type and quality. It is anticipated that process guarantees for anaerobic digestion will be feedstock specific. One of the benefits of using anaerobic digestion as a technology is that it can handle high moisture feedstocks; however because of its higher moisture content there may be higher transportation costs for delivery of the feedstock to the facility.

**By-Product Disposal**

Waste Energy Solution's digester produces two co-products: a liquid fertilizer product, and a solid product suitable for use as bedding and potting material. The liquid fertilizer product can best be utilized by local markets, primarily the producers supplying the manure to the facility in the first place. The solid material can be transported to exterior markets.

**B. RCM Biothane**

Biothane Corporation, recently acquired by RCM, is one of the leading anaerobic digester design companies in the United States. RCM-Biothane specializes in livestock digesters, from lagoons to complete mix and plug flow for both dairy and swine operations. Biothane has been in industrial wastewater treatment since 1979 and is based out of New Jersey. RCM and Biothane have 400 full-scale plants in operation worldwide.

Contact information for RCM-Biothane:

Denise A. Johnston  
VP Marketing and Sales  
RCM Biothane  
2500 Broadway/D-5

Camden, NJ 08104  
Ph: (856) 541-3500  
www.biothane.com

RCM-Biothane recommends an Upflow Anaerobic Sludge Blanket (UASB) high-rate reactor for the West Michigan project. This high rate process uses simple but efficient internal settlers to effectively degasify the biomass and ensure it is retained within the reactor vessel. According to RCM-Biothane, full scale applications of this process have been in operation for more than 25 years. The RCM-Biothane UASB reactor is designed to operate at high chemical oxygen demand (COD) loadings (10 to 15 kg COD/m<sup>3</sup> of reactor volume per day). The high loading translates into a short hydraulic retention time; RCM-Biothane claims the HRT is less than 48 hours for most applications.

#### How the RCM-Biothane Process Works

Wastewater enters the bottom of the digester through the inlet distribution system and passes upwards through the dense anaerobic sludge bed. Soluble COD is readily converted to biogas (which is rich in methane) and an upward circulation of water and gasborne sludge is established. The specially constructed settler sections allow effective degasification to occur. The dense, granular sludge particles, now devoid of attached gas bubbles, sink back to the bottom establishing a return downward circulation.

The upward flow of gasborne sludge through the blanket combines with the return downward flow of degassed sludge and creates continuous convection. This insures effective sludge to wastewater contact without the need for any energy-consuming mechanical or hydraulic agitation within the reactor. The design of the digester allows a highly active biomass concentration in relation to soluble organic solids passing through the sludge bed.

The RCM-Biothane UASB Process creates a stream circulation through the double baffle-plated settler design: gasified sludge enters and exits the settler on separate paths.

The digester for the West Michigan Regional Liquid Livestock Manure Processing Center would be an aboveground, bolted-steel epoxy-coated tank, externally insulated with an internal liquid-to-liquid heat exchanger. The insulation is protected from the elements with a custom fabricated metal cladding. The tank has a flat, floating insulated top that is completely sealed to prevent unintended gas escape. The roof is manufactured with a rainfall collection and removal system that is capable of withstanding wind, rain, and snow loads likely in the area.

According to RCM-Biothane, minimal nutrient removal through the anaerobic process will occur, and nitrogen is converted to ammonia. The effluent from the digester is treated in the UASB anaerobic wastewater treatment system, which reduces COD levels of the digester effluent from 6,600 mg per liter to 563 mg per liter.

The RCM-Digester is capable of handling 100% swine manure influent. RCM-Biothane used these assumptions in preparing their quotation:

- 100,000 gallons per day of swine manure
- Total solids content of manure at 4%
- Volatile solids in swine manure at 2%
- Biological oxygen demand (BOD) at 0.25 lbs per day

### Products

The RCM-Biothane Digester biogas has 65% methane content. This digester generates approximately 5,100 m<sup>3</sup>/day of biogas (at 65% methane content), which provides approximately 117 mmBTU/day for energy use, or 40,850 mmBTU per year. Gas availability is net of the parasitic load required to run all equipment for the anaerobic digestion system.

System components included in the RCM-Biothane capital estimate:

- Influent Tank; pre-cast concrete or coated steel with a 50,000 gallon volume
- Anaerobic Manure Digester; coated bolted steel with catwalk with a ladder and safety cage, volume of 2,153,000 gallons (114ft diameter, 28ft height)
- Digester Sidewall Insulation
- Digester Mixing Capability
- Floating membrane cover complete with gas removal
- Heat Exchanger with support and base
- Automatic safety flare
- Prefab Gas and Hot Water container
- Gas Handling Skid
- Hot Water Skid
- Wastewater treatment system: 66,000 gallon, coated-steel RCM-Biothane reactor vessel, 34 ft long x 14ft wide x 20 ft height
- Miscellaneous pumps, instrumentation, piping and mechanical

Capital costs vary based on the level of water treatment desired. RCM-Biothane commented that to sufficiently treat the digestate for *groundwater disposal* will require both an anaerobic treatment and an aerobic treatment system. The budget price for the aerobic treatment system quoted by RCM-Biothane was \$695,000, including freight and installation of the system. Note that the aerobic treatment is not included in the financial analysis.

Capital costs, operating costs and the outputs from the anaerobic digestion process are shown in the following tables. Project engineering and construction management is included in this quote. The digestate produced by RCM-Biothane's digester is considered sludge, with total solids of approximately 1.5%. The anaerobic treatment removes harmful pathogens in the sludge but does not provide solid separation. FBA estimates that to separate the solids in the treated wastewater a solids separation unit would need to be added, at a cost of approximately \$750,000; FBA included this cost in the estimate below:

**Table 16: RCM-Biothane  
Anaerobic Digestion Facility  
100,000 Gallons Per Day System**

	<b>Capital Cost</b>
RCM-Biothane UASB Digester	\$3,000,000
Anaerobic Wastewater Treatment System	\$750,000
Solids Separation Unit	\$750,000
Site Preparation	\$225,000
Engineering	(Included)
Management & Training	(Included)
Startup Costs	\$450,000
Contingency (15%)	\$828,750
Land	\$100,000
<b>Total Installed Cost</b>	<b>\$6,353,750</b>

**Table 17: Anaerobic Digestion Revenue Outputs  
Using 100% Swine Manure**

<b>Revenue Category</b>	
Biogas Available (per year)	1,780,000 m <sup>3</sup>
Methane Gas Available (mmBTU/year)	40,850 mmBTU
Digestate (tons/year)	13,500

A similar up-flow sludge blanket digester was built by Biothane in 1982 for Ore-Ida Foods to handle wastewater from potatoes. This system was in Plover, Wisconsin, and generated approximately 1,370,000 m<sup>3</sup> per year of biogas. The total cost for the reactors was \$3 million (two tanks built in 1982 and 1987); at a 3% price increase per year, this would equate to approximately \$5,400,000 cost using today's dollars. The treated sludge from this digester was dried on a belt press and used as a fertilizer. The biogas had no host but instead was used by Ore-Ida for its own use in cooking potatoes<sup>18</sup>.

### Environmental Impact

There is no foreseeable environmental impact with the RCM-Biothane digester (assuming that a solution for the disposal and/or treatment of the wastewater has been determined). The RCM-Biothane wastewater must meet EPA discharge permit limits. RCM-Biothane recommends that due to the higher costs and difficulties associated with handling the digester wastewater, treatment should be handled by a third party. However, costs were provided for FBA's analysis, which are reflected in the Financial Analysis section. No costs were included in the operating cost for environmental compliance other than the maintenance and personnel required to run the equipment for the treatment of the water.

<sup>18</sup> Biogas Energy Systems, A Great Lakes Casebook. Great Lakes Regional Biomass Energy Program. Prepared by J.K. Cliburn & Associates. May 1993.

### Siting

The site requirements for the RCM-Biothane anaerobic digestion presumes a flat, clear and accessible with a minimum soil bearing value of 3,000 psf, no overhead or underground obstructions and no-sub-surface abnormalities.

### By-Product Disposal

The RCM-Biothane treated digestate is projected to have a COD concentration of less than 563 mg/liter. This material is suitable for land application as a fertilizer replacement.

### **C. Andigen**

Andigen's complete mix digester is an Induced Blanket Reactor (IBR). The principal feature of this digester is the super rich concentration of digesting bacteria, which promises a greater performance. The IBR system uses reactor tanks that may be placed above or below ground. Swine manure or other influents are heated before entering the digester tank. The IBR operates in the mesophilic temperature range, and is designed to handle up to 10% solids content in the influent stream.

Contact information for Andigen:

Ed Watts  
Andigen, LC  
Logan, UT  
Ph: (435) 770-3766  
www.andigen.com

The influent enters the lower part of the tank and gradually moves upward through a super-rich bacteria blanket where digestion and gas production occurs. This size of digester (100,000 gallons per day) is designed for a HRT of five days.

Included in the capital estimate is sufficient storage for 350,000 gallons (3.5 days).

Performance specifications for the Andigen Digester:

- 108 mmBTU generated per day; this is 4,370 m<sup>3</sup> of biogas; approximately 3 mmBTU is required for parasitic load, netting 105 mmBTU/day
- Biogas is 70% methane content
- H<sub>2</sub>S content of the biogas is less than 800 ppm
- 21,000 square feet area requirement for digester, influent storage, and working space
- Total solids reduction of 50% to 55%

The components included in the system cost for the IBR System include:

- IBR anaerobic digester reactors
- Electro-coagulation wastewater treatment
- Insulated steel building

- Influent pumps and grinders
- Influent heat exchangers
- All required sensors and flow-meters
- Electronic control system automation
- Startup and Backup boilers
- Emergency flare
- Component delivery

The assumptions used by Andigen in preparing their quotation are the Base Case:

- 100,000 gallons per day of swine manure
- Total solids content of manure at 4%
- Volatile solids in swine manure at 2%
- Biological oxygen demand (BOD) at 0.25 lbs per day

Andigen provides a treatment of the effluent digestate using electro-coagulation. This process has an ongoing treatment cost of \$1.00 to \$1.75 per million gallons (\$0.10 to \$0.175 per day). No solids separation was included in Andigen's quotation; FBA added \$750,000 for the installation of a solids separator unit to reduce the moisture of the effluent to 35% total solids. A capital cost summary is shown below. A detailed financial proforma, including operating costs, is included in the Addenda.

<b>Table 18: Andigen Anaerobic Digestion Facility 100,000 Gallons Per Day System</b>	
	<b>Capital Cost</b>
Andigen IBR System	\$2,007,000
Electro-Coagulation Treatment	\$200,000
Solids Separator Unit	\$750,000
Influent Holding Pit & Pumps	\$175,000
Engineering	\$156,600
Management/Training	\$62,640
Licensing/Labor	\$62,640
Site Preparation	\$156,600
Startup Costs	\$313,200
Contingency (15%)	\$597,552
Land	\$100,000
<b>Total Project Cost</b>	<b>\$4,581,232</b>

<b>Table 19: Anaerobic Digestion Revenue Outputs Assuming 100% Swine Manure Feedstock</b>	
<b>Revenue Category</b>	<b>Quantity</b>
Biogas Output (per year)	1,530,000 m <sup>3</sup>
Methane Gas Available (mmBTU/year)	36,681 mmBTU
Digestate (tons/year)	13,500
Digestate Value	\$472,500

### Environmental Impact

Environmental impact from Andigen digester is similar to the previous suppliers. No costs were included in the operating cost for environmental compliance other than the maintenance and personnel required to run the equipment for the treatment of the water.

### Siting

The site requirements for the Andigen facility are approximately 21,000 square feet for the digester, influent storage, and working space.

### By-Product Disposal

The Andigen digester produces a liquid effluent treated with electro-coagulation. This material is suitable for land application as a fertilizer replacement.

### **D. Biopower Technologies, Inc.**

Biopower Technologies, Inc. is a technology supplier offering a lower-cost solution to traditional anaerobic digestion technologies. Biopower Technologies claims that its digester can handle swine manures mixed in combination with other biomass materials, limited only to the maximum solids handling of the digester (7.5% total solids). A solids content of higher than 7.5% is not prohibitive, but will seriously affect the performance of this digester by inhibiting the microbial activity responsible for methane generation.

The contact information for Biopower Technologies:

Olaf Riedel  
Biopower Technologies  
5178 NW 108 Ct.  
Miami, FL 33178  
Ph: (305) 513-0306  
www.biopowertech.com

Biopower Technologies is marketing a modification to a process being commercialized in Europe, a variant of a *Fixed-Film Digester*. In a fixed film digester, the tank's interior surface is covered with a layer of bacteria, which grow on the fixed-film. The influent passes through the digester and the bacteria break down the material. The number of bacteria in a fixed-film digester is higher than

typical complete-mix digesters. The main advantage of a fixed-film digester is a significant reduction in the HRT to two to six days<sup>19</sup>, as well as the reduction in the footprint requirements for the digester facility. Biopower Technologies' digester has a HRT of 3 to 5 days.

#### Biopower's Process in Detail

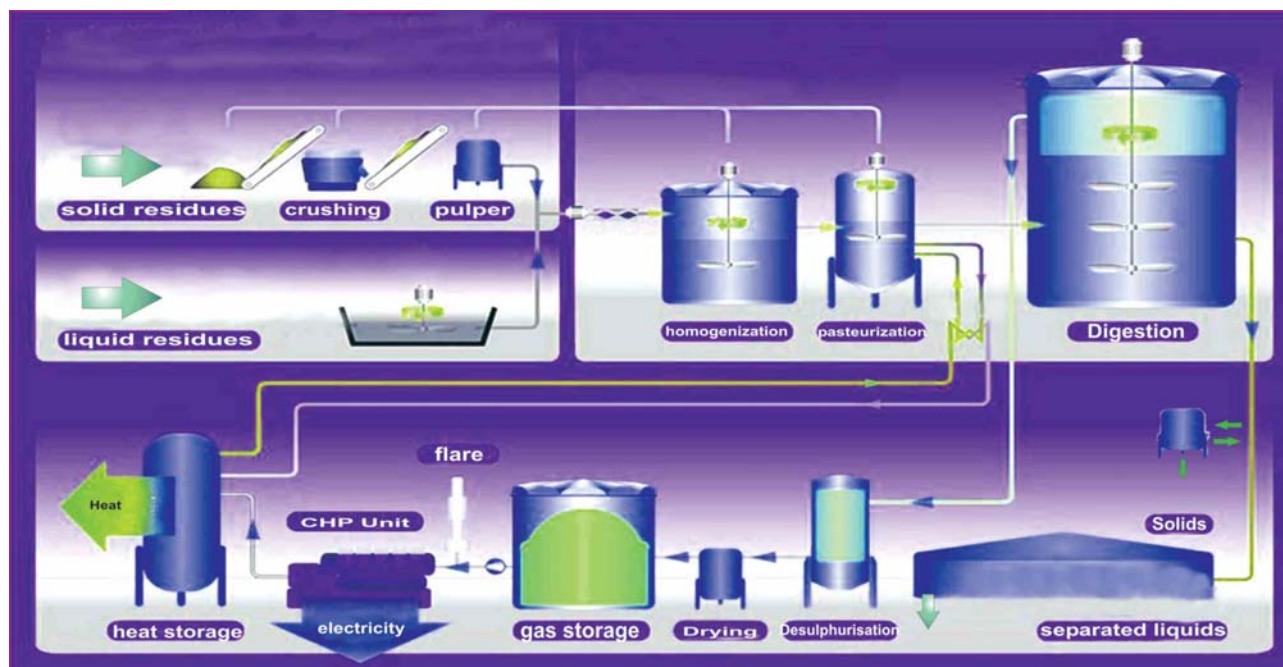
- Swine manure is transported and held in a receiving tank with a two-day capacity.
- Solid feedstocks are processed in a grinder to reduce particle size
- Materials are mixed in a mixing unit to equalize the stream of incoming feedstocks to the digester, providing a consistent flow to minimize impact on bacteria
- The feedstock is pasteurized in a pasteurizer for at least one hour at 158°F to 194°F. Heat loss is minimized to less than 1°F during this period.
- After pasteurization the feedstock is pumped with a chopper pump through heat exchangers and then to the main pump.
- The material gives off heat to the heat exchangers, cooling to approximately 104°F before being fed to the digester.
- Material enters the digester where the breakdown of the organic acids and production of biogas occurs in the proprietary fixed film digester. The digester operates in mesophilic temperature at approximately 98.6°F.
- Methane gas is desulphurized and stored. Gas is dried to remove remaining pollutants.
- The digestate effluent is treated in a post-digestion water treatment process.

The diagram below is one example of how a Biopower Technologies anaerobic digester can work (this particular example includes electricity generation through a combined heat and power unit, or CHP, but electrical generation has not been quoted for the West Michigan project).

#### **Chart 3: Biopower Technologies Process Flow Diagram**

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<sup>19</sup> (2005). AgStar Program. Fixed Film Anaerobic Digester. U.S. Environmental Protection Agency. <http://www.epa.gov/agstar/resources/biocycle4.html>



Source: Biopower Technologies

### Water-Treatment

In the post-treatment of the digestate, the effluent stream is separated into water and the remaining solids. This involves a proprietary chemical process where particles are formed in a controlled size and rate. It is essentially a reverse-osmosis (RO) process that works by filtering the digestate through a membrane, where solid particles collect on a filter. During the treatment process the material forms uniform sized particles as they are deposited on the membrane. After filtration, a back-flush occurs and the solid material is extracted from the membrane. This process was developed by Waste Water Solutions and licensed by Biopower Technologies for use on its digester.

This process creates two co-products: a biosolid stream of the remaining solids and dry matter with 35% to 50% solids; and a liquid effluent that, according to Biopower Technologies, can be environmentally disposed of. The expected BOD content in the liquid stream after separation is below 9 mg/liter, and COD is below 9 mg/liter.

System components included in the capital estimate:

- Engineering, construction, and foundations
- Grinding unit
- Pasteurization (heated) unit
- Heat exchanger
- Digester with volume of 300,000 gallons
- Desulphurization
- Piping and various required mechanical equipment
- Training of operation staff

Biopower Technologies claims a biogas yield of 10 m<sup>3</sup> per ton of swine manure at 4% total solids. A volume of 100,000 gallons of swine manure equates to 1,430,000 m<sup>3</sup> of biogas per year. The Biopower Technologies digester offers a 60 to 70% methane quality in the biogas; FBA assumes 65%; this gives 32,798 mmBTU per year. Gas availability is net of the parasitic load required to run all equipment for the anaerobic digestion system.

The treated semi-solid digestate material has a potential value as a fertilizer. Biopower Technologies claims there is virtually no N, P or K loss during the digester process and little loss during water separation. Based upon data provided by this vendor, FBA estimates that this digester will generate 13,500 tons per year of treated digestate material. Biopower Technologies claims this treated digestate has a 35% to 50% total solids content; FBA assumed a conservative 35%.

Biopower Technologies used the following assumptions in preparing their quotation:

- 100,000 gallons per day of swine manure
- Total solids content of manure at 4%
- Volatile solids in swine manure at 2%
- Biological oxygen demand (BOD) at 0.25 lbs per day

Capital costs, operating costs and the outputs from the Biopower Technologies anaerobic digester are shown below.

<b>Table 20: Biopower Technologies Anaerobic Digestion Facility 100,000 Gallons Per Day System</b>	
	<b>Capital Cost</b>
Receiving Unit	\$80,500
Agitator	\$13,800
Grinding Unit	\$103,500
Pasteurization Unit	\$103,500
Heat Exchanger	\$69,000
Pumps	\$115,000
Digester System	\$437,000
Medium for fix film	\$69,000
Dewatering System	\$828,000
Storage	\$115,000
PLC, SPS controllers	\$210,000
Piping	\$138,000
Startup Costs	\$239,642
Engineering	\$114,115
Management & Training	\$150,000
Licensing/Labor	\$250,000
Site Preparation	<u>\$119,821</u>

Contingency (15%)	\$488,382
Land	\$100,000
Total Capital Investment	<b>\$3,744,259</b>

**Table 21: Anaerobic Digestion Products**  
**Assumes 100% Swine Manure**  
**100,000 Gallons/Day**

Revenue Category	
Biogas Output (per year)	1,430,000 m <sup>3</sup> /year
Methane Gas Available at 65% Biogas (mmBTU/year)	32,798 mmBTU
Treated Digestate (tons/year)	13,500

### Environmental Impact

Biopower Technologies has included in its capital estimate a proprietary technology for the treatment of the liquid component of the digester effluent. Biopower Technologies claims this technology will allow the treated wastewater to be safely discharged into the public sewer system. Annual operating costs include the cost for environmental compliance but do not include the possible charge from the public sewer system.

### By-Product Disposal

The Biopower Technologies digester produces a treated semi-solid (35% solids) material suitable for use as compost or fertilizer material. The other by-product is treated wastewater, which can be disposed of through the public sewer.

### Applied Technologies

FBA contacted Applied Technologies late in the feasibility study stage due to concerns that the first four vendors' quotations were too high. Applied Technologies designed the duck complete mix system that is discussed in the Agricultural Biogas Casebook. FBA requested a preliminary budget estimate from this supplier and obtained it in mid-April. Contact information for Applied Technologies:

Dennis Totzke  
 Applied Technologies  
 16815 West Wisconsin Avenue  
 Brookfield, WI 53005  
 Phone: (262) 784-7690

### Parameter Design Assumptions:

- Flow of 100,000 gpd of swine manure
- COD, mg/L 60,000 (estimate)
- BOD, mg/L 30,000
- TSS, mg/L 45,600

- FOG, mg/L 800 mg/L (estimate)
- TKN, mg/L < 500 (estimate)
- T-P, mg/L 25 (estimate)
- pH, s.u. 6 to 8 (estimate)
- Ambient Temperature

The various components for the proposed anaerobic contact process system are listed below. Not included in these components is a recommend influent equalization of at least 12 hours.

#### Anaerobic Contact Process Reactor

- HRT 24 days
- OLR 2.5 kg COD/m<sup>3</sup>.d
- Working volume about 2,400,000 gallons
- Reactors nominal height: 32 feet (two reactors)
- Reactors nominal diameter: 82 feet (two reactors)
- Reactor side water depth 30 feet
- Gas space should be of corrosion-resistant material
- Tank can be of reinforced concrete, epoxy-coated steel, stainless steel, or glass-lined steel
- Cover can be concrete, steel, or flexible membrane
- Consider insulating the tank sidewalls and cover (e.g., 1-inch spray foam)

#### Anaerobic Degas Tower:

- Atmospheric cascade (uses FRP plates inside the tower to create splashing effect)
- FRP solid cover on top for odor control
- Same height as the reactor
- Tank 12 feet by 12 feet in area
- Anaerobic Contact Gravity Clarifier
- Nominal diameter 40 feet
- Nominal side water depth 14 feet
- Suction mechanism (e.g., Envirex Tow-Bro)
- FRP covers on overflow weirs if concerned about odors, do not cover entire clarifier surface
- Clarifier tank can be of concrete or coated steel

#### Return Anaerobic Sludge (or DAF Float) System:

- duplex (1+1) pumps (variable speed/flow)

#### Biogas Handling System:

- Two combination vacuum and pressure relief valves with isolation valves
- Gas collection port/dome in cover
- Sampling ports (minimum of two) and access hatchways (minimum of 1) in reactor cover
- Condensate/sediment trap

- Pressure regulator
- Small condensate traps at low points in biogas line
- Low-pressure switch (if use flexible membrane cover)
- Biogas extraction blower (if use flexible membrane cover)
- Flare with automatic igniter

**Biogas Usage/Reactor Heating System:**

- Hot water boiler with hot water recirculation pumps
- Spiral heat exchanger
- Reactor mixed liquor feed/recirculation pump(s)

For this application, Applied Technologies thinks the preferred anaerobic system would consist of a concrete tank with a 1-inch thick insulated flexible membrane cover with stainless steel support cables (e.g., GTI, Lemna) and a concrete gravity clarifier and mechanism as the solids separations unit. Heating should be via a boiler and spiral heat exchanger. They estimate 150 to 250 ft<sup>3</sup> per minute of biogas at 60% methane to be generated at 85% COD removal; FBA assumed 200 ft<sup>3</sup> per minute of biogas; this equates to about 20 m<sup>3</sup> of biogas per ton of swine manure. They also suggest doing a bench-scale anaerobic degradation study to better determine the optimal HRT and organic loading rates for this particular wastewater. This can be provided by Applied Technologies in a separate study.

Capital costs, operating costs and the outputs for the Applied Technologies anaerobic digester are shown below.

<b>Table 22: Applied Technologies Anaerobic Digestion Facility 100,000 Gallons Per Day System</b>	
	<b>Capital Cost</b>
Digester tanks w/cover and mixers	\$1,500,000
Solids Separation Unit*	\$750,000
40' Diameter clarifier	\$92,000
Manure mixing/feed pit w/pumps	\$35,000
Sludge circulation pump	\$25,000
Sludge transfer/recirculation pump	\$25,000
Heat exchanger	\$70,000
Misc. Equipment (pumps, meters, etc.)	\$20,000
Control building	\$90,000
Waste gas burner and safety equipment	\$45,000
Mechanical	\$285,000
Site civil	\$114,000
Electrical	\$190,000
Instrumentation/Control	\$152,000
Administration & Engineering	\$127,000
Site Preparation	\$132,600

Startup Costs	\$265,200
Contingency (15%)	\$602,670
Land	\$100,000
Total Capital Investment	<b>\$4,620,470</b>

\* FBA added a solids separation unit to the capital cost items

As seen here, the total capital investment is in-line with three of the other system quotations supplied for this report.

The Applied Technologies digester requires one operator working 4 to 8 hours a day, 350 days/year. With benefits the labor rate suggested by Applied Technologies is \$30 per hour, or \$42,000 to \$84,000 per year. Maintenance expense is approximately 2% of total capital cost.

A product summary is provided below:

<b>Table 23: Anaerobic Digestion Products</b> <b>Assumes 100% Swine Manure</b> <b>100,000 Gallons/Day</b>	
Revenue Category	
Biogas Output (per year)	2,854,804 m <sup>3</sup> /year
Methane Gas Available at 60% Biogas (mmBTU/year)	58,675 mmBTU
Effluent:	80,000 gallons/day

NOTE: The only information FBA was given was the estimated volume. No characterization of the chemical constituents of the effluent was provided by Applied Technologies. Because the information here was provided to FBA only two days before this final report was submitted, a full detailed analysis was not possible.

### **GHD, Inc.**

A sixth vendor, GHD, Inc., was also contacted for this project. GHD's technology is a combination plug flow/complete mix system and it was felt it may be a fit for the Michigan project. According to Melissa Dvorak, Marketing Manager for GHD, this digester is currently being used with dairy manure operations. Dairy manure generally has a higher solid content than swine manure but the digester is being supplemented with various substrate wastes. Ms. Dvorak said GHD's technology could be used with a swine manure operation; however, she was concerned that the economics might not work with GHD's digester due to transportation costs. The majority of GHD's operations are set up on-farm, minimizing the collection of the waste, and these are the ideal scenarios for such an operation. Given their concerns, and because GHD did not believe its technology could be financially feasible for a centralized swine collection digester, Ms. Dvorak withdrew its technology from this project and provided no quotation.

### **CO<sub>2</sub> Collection**

CO<sub>2</sub> is not normally collected. Biogas is principally methane and carbon dioxide. A biogas with 65% methane content contains approximately 30% CO<sub>2</sub> by volume. Collection of CO<sub>2</sub> should only be considered if there is an available host for the CO<sub>2</sub> produced by an anaerobic digester. This requires a scrubber, which has been estimated at approximately \$500,000 for this size of project. This expense was not included in the above capital cost projections, or in the financial analysis for this study.

### E. Summary

A summary of the technology providers is shown below. These capital costs are, in FBA's opinion, high relative to operational digesters. For example, the complete mix outlined in the Agricultural Biogas Casebook (a duck farm generating approximately 45,000 gallons per day of 2% solids manure) had an installation cost of \$804,000 including an electricity generating set. No information was available on the biogas recovered at this digester to make a full comparison.

The costs for WES (and to some extent the other vendors) is higher than expected due to their inexperience in anaerobic digestion of mortality. To FBA's knowledge there are no operating swine complete mix digesters of comparable size (100,000 gallons per day) that utilize mortality or offal as a supplementary feedstock.

**Table 24: Summary of Anaerobic Digestion Technology Suppliers**

	WES	RCM-Biothane	Andigen	Biopower Tech.	Applied Tech.
Feedstock	100,000 Gallons/Day of Swine Manure				
Total Solids in Feedstock	4%	4%	4%	4%	4%
Total Solids Allowed by Digestate	10%	10%	10%	7.5%	10%
Solids Separation Unit Attached?	Yes	No	No	Yes	No
Digestate Treatment?	Yes	Yes	Yes	Yes	Yes
Liquid Digestate	Yes	Yes	Yes	No	Yes
Semi-Solid Digestate	Yes	No	No	Yes	No
Methane Content of Biogas	75%	65%	70%	65%	60%
Methane Generation Per Year	43,933 mmBTU	40,850 mmBTU	36,681 mmBTU	32,798 mmBTU	N/A
Capital Cost	\$12,478,363	\$6,630,000	\$4,780,416	\$3,634,998	\$4,620,470
Operation Cost Per Gallon*	\$0.044	\$0.024	\$0.018	\$0.014	N/A
CO <sub>2</sub> Production Per Year	18,200,000 ft <sup>3</sup>	21,367,500 ft <sup>3</sup>	15,666,300 ft <sup>3</sup>	17,155,800 ft <sup>3</sup>	40,320,000 ft <sup>3</sup>

\* Includes depreciation & interest

Basis conversations with the various technology suppliers, FBA concludes one of the major determining factors for the success of this operation is the collection of the waste material on a periodic basis. An anaerobic digester requires constant feeding, certainly no less than once every

two or three days. Collecting swine manure two times a year from local producers is not an option. One recommendation would be to set up a series of collections from each producer on a periodic basis to assure a constant stream of material to the central processing facility.

Another determining factor for success is proper disposal of the wastewater. In most cases there is little economic benefit realized by the digester treating the water, as the costs associated with treatment and handling of the wastewater are high compared to the size of the digester.

One of the goals of this project was to find a method of disposing of the liquid manure from local swine producers. The four technology providers contacted by FBA differed in cost, output of biogas, and the properties of the effluent (digestate) from the digester. All the technologies have a different efficiency at which biogas can be captured from a feedstock, usually a higher biogas production equates to a higher capital cost due to increased system demands.

The technologies varied as well in the type of digestate produced. Three of the technologies contacted provided no quotation for solids separation; in their experience swine digestate is more economical as a land applied fertilizer replacement. The best-case scenario for treatment of the digestate provides a material that is still 50% to 65% in moisture—and there is still the problem of disposing of the wastewater. Treatment of the wastewater to remove pathogens and to allow its proper disposal (if it is not going to be used as a land applicant) is an added cost above that required by the digester and the solids separation unit. Additionally, from discussions with RCM-Biothane, the full disposal of the wastewater will require not only anaerobic treatment, but aerobic treatment as well. Only one of the vendors, Biopower Technologies, proposed a full system to accomplish these steps.

It is critical that the West Michigan LLMPC be well designed and well managed to avoid failure. Iowa State University estimates that, historically, there is a 63% chance a new digester will fail<sup>20</sup> although most of these failures resulted from a number of digesters being built in the 1970s during the energy crisis. The reason for their failure remains appropriate to this project: failure was due to poor design and poor management of the digester. Selection of the best fit digester for the project is the first step to success.

A study of the financial returns for these technology providers is included in the Financial Analysis section.

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<sup>20</sup> Ernst, M., et al. Viability of Methane Production by Anaerobic Digestion on Iowa Swine Farms. Iowa State University. ASL-R1693.

## V. Project Market Factor Analysis

An anaerobic digester usually produces two revenue product streams: methane derived from biogas, and the digestate. A thorough discussion of each of these products follows.

### A. Methane

The base case for this feasibility study calls for the Liquid Livestock Manure methane gas output to be marketed via existing, privately owned methane gas transportation infrastructure (Gas pipeline) located in Zeeland Township. This existing infrastructure already facilitates the delivery of methane landfill gas from near the proposed project site at the corner of Adams and 56<sup>th</sup> Avenue to the east side of Zeeland Michigan near Chicago Drive and 84<sup>th</sup> Avenue at Zeeland Farm Services, Inc.'s (ZFS) facilities. The infrastructure is the result of a project undertaken by Waste Management of Michigan, Inc. (WM), North American Natural Resources, Inc. (NANR), and ZFS.

Utilizing this existing infrastructure allows the Liquid Livestock Manure Processing Center (LLMPC) to be located in a rural, low-density area more conducive to manure transport and processing while providing better access to end-markets for methane gas via the gas pipeline. The end-market possibilities facilitated by the pipeline include consuming the methane for steam and heat production and/or generating renewable electricity. For the renewable electricity generation alternative, the Northwest end of the pipeline allows for lower-cost and simpler attachment to the electricity grid system.

**Map 3: Proposed Anaerobic Digester Location**



### Methane Gas Transportation Infrastructure Description and Introduction to Participants

Waste Management (WM) built, owns, and operates the Autumn Hills Recycling and Disposal Facility (Autumn Hills) on the southeast corner of Adams and 56<sup>th</sup> Avenue. Autumn Hills recovers and collects methane gas generated by the anaerobic decomposition of solid waste in the landfill. WM is a leading provider of comprehensive waste management services. Based in Houston Texas, the Company serves municipal, commercial, industrial, and residential customers throughout North America. WM supplies landfill gas to 85 landfill gas-to-energy projects in 25 states. In all, its gas-to-electric projects alone provide more than 200 megawatts of energy, enough to power approximately 215,000 homes.

NANR built, owns, and operates a methane gas cleaning, drying, and compressing facility contiguous to the landfill. NANR, based out of Okemos Michigan, is focused on identifying, building, and operating natural, renewable, energy-based facilities to improve the environment while providing novel sources of energy to commercial users. NANR currently has three landfill gas-to-energy plants located in Birch Run, Lennon, and Whitehall Michigan with a total of seven electric generating units. NANR, along with its affiliates, has facilitated various energy projects utilizing waterway dams, landfill gas, and wind.

ZFS built, owns, and operates the pipeline to transport gas from NANR's facility to its own site at 2468 84<sup>th</sup> Avenue in Zeeland, Michigan. ZFS converts the existing landfill gas flowing through the pipeline into steam and electricity with existing equipment and operational people. ZFS, based out of Zeeland Michigan, is a 55 year-old company that employs 150 people. Its biggest division, Zeeland Farm Soya, owns and operates Michigan's only soybean processing plant to utilize solvent extraction to produce high-protein soybean meal and soybean oil. Other divisions include Zeeland Freight Services, a 70-truck fleet that transports bulk commodities in the Midwest and Southeastern U.S., Zeeland Farm Services, a market provider of grains, feed ingredients, and agronomy products in the Midwestern and Southeastern U.S., and Zeeland Food Services, which refines and bleaches vegetable oils and sells SelectOil™, a low saturated fat soybean oil.

### Methane gas value into pipeline

After examining the economics for various consumers of the gas at the end of the pipeline based upon historical pricing of competing energy costs through July 2005, a value of approximately \$3.35 per million British Thermal Units (mmBTU) is expected to be available to the LLMPC.

From August 15, 2005 through the date this report was issued natural gas prices reached unprecedented lifetime-highs. Hurricane Katrina was a natural catastrophe that contributed to unusual pricing because it occurred during the midst of already tight markets. The methane values outlined below are based on the assumption that the August to December 2005 energy markets represented a temporary spike in generally increasing energy prices. If the lifetime high natural gas prices show staying power through 2006, all the values outlined below represent conservative levels considered highly achievable.

### Scenario #1 – Methane gas for Green Power

Two primary scenarios may be possible to realize the \$3.35 per mmBTU price at the LLMPC. The first, utilizing the gas to generate green power at ZFS's facility to be sold on the electric grid, is outlined below:

Potential Green Power Price per Kilowatt Hour (kWh)	\$0.0600
Federal income tax credit	0.0037
Less generator maintenance costs	(0.0117)
Less capital cost	(0.0135)
Less Administration and operations costs	(0.0035)
Less gas cleaning, drying, compression, & transportation cost	<u>(0.0080)</u>
Margin per kWh available to LLMPC	\$0.0270

The \$0.0270 margin per kWh converts to \$3.35 per mmBTU based on 8,000 Higher Heating Value (HHV) BTUs required to generate one kWh through co-generating steam and electric with a reciprocating engine. The co-generation efficiency compares to a 9,600 HHV BTU heat rate required to generate one kWh without co-generating steam. This conversion of BTUs to kWh is based on actual specifications for Caterpillar's latest reciprocating engine generator technology incorporated into its 3520C generator package capable of producing 1,600 KW per hour. This engine package, with daily demand for 370 mmBTUs at a 100% load, closely matches the supply of methane gas from the 100,000 gallons per day LLMPC with an approximate daily supply of 350 mmBTU per day (350 operating days per year).

The figures above were derived based on the following information and assumptions:

1. There is a continuing push by the Michigan Public Services Commission to have Michigan utilities incorporate renewable power in their portfolios. If this trend continues, green power pricing should be available in the \$0.055 to \$0.065 per kWh range based on recent green power pricing indications with Michigan utilities.
2. The federal tax credit assumes the current \$0.0095 per kWh tax credit rate less a 61% discount due to the credit being available only for the first 5 years and the potential for the generator operator to not have federal income tax liabilities to be offset by the credit.
3. Generator maintenance costs are based on Caterpillar maintenance recommendations and current part costs.
4. That ZFS is able to utilize the recaptured steam to enable the efficient 8,000 BTU heating value efficiency versus 9,600 BTUs without steam.

5. Capital cost is based on \$1,300,000<sup>21</sup> total electric generation system cost to install one Caterpillar 3520C engine with all required infrastructure, an 11% cost of capital, a 15-year period of operation, and a \$100,000 residual value after 15 years. This capital cost does not include land and substantial electricity grid connection costs. Electricity grid connection costs can vary widely from \$40,000 to \$500,000 depending on the location of the generation. These costs are minimized if the generation is done at ZFS's existing site.
6. Administration and operation costs include insurance, labor and professional services to manage electric sales contracts, operate the generator on an hourly basis, and arrange maintenance services. This cost may also include property taxes during the last 6 years of operations due to potential expiration of tax exemptions.
7. Gas cleaning, drying, compression, and transportation costs include NANR and ZFS costs to receive, clean, dry, and compress the gas near the LLMPC and then transport the gas approximately 6 miles to ZFS's location where electric generation would take place.
8. All figures above assume gas supply and electric generator run-time would average 92% of all annual hours (336 days per year) at 100% generator load.



**Caterpillar 3520C 1,600 KWH Low-BTU Gas Genset without Co-Generation**

#### Scenario #2 – Methane gas for a steam or electric host

The second scenario calls for the gas to be re-sold to another steam or electric host in the Zeeland area:

Price paid by end-user per mmBTU	\$3.90
Less gas cleaning, drying, compression, & transportation cost	<u>(0.80)</u>

<sup>21</sup> This generation set was based on a projected 110,000 mmBTU output; actual costs to be determined after anaerobic digestion technology and its methane gas output are finalized.

Price per mmBTU available to LLMPC

**\$3.10**

The end-user price of \$3.90 per mmBTU represents an approximate value that may be realized assuming gas is delivered to the end-user's location on a long-term Agreement.

#### Challenges for Digester Gas End-Users

The end-user has increased costs, risks, and operational issues running on renewable methane gas when compared to natural gas. The challenges are generally due to the fact that the gas is an unfamiliar and less consistent source of energy. These challenges are explained in more detail below.

1. Lower and varying BTU content per Standard Cubic Foot (SCF) of gas. Digester methane gas contains approximately 60% methane (CH<sub>4</sub>) content compared to effectively 100% methane content in natural gas. This directly reduces the BTU content of the gas, which determines the energy available to gas consuming equipment in proportion to the gas flow. Where digester gas contains 600 BTU per SCF, natural gas contains 1,000 BTU per SCF. The lower BTU content requires gas-specific equipment to utilize the gas for heat, steam, or electricity generation.
2. Digester gas contains hydrogen sulfide (H<sub>2</sub>S), a corrosive and toxic compound found in digester-derived gas<sup>22</sup> as well as landfill gas. This toxicity requires steam generating equipment accessories to be converted to more durable materials. For instance, gas piping, valves, meters, etc. must be constructed or replaced with stainless steel, contributing to capital costs for the gas user. Due to the digester gas being commingled with landfill gas to utilize gas transportation infrastructure, the gas will also contain siloxanes, which are chemicals in lubricants and personal care products like cosmetics, hair spray, and deodorants that are disposed in solid waste landfills<sup>23</sup>. These siloxanes can potentially increase maintenance and cleaning costs to steam generation equipment and shorten the useful lives of equipment.
3. Significant capital is required to convert or add necessary equipment. Boilers require unique burners and control systems to properly burn the lower and varying BTU gas. Reciprocating engines must be built or modified specifically for low BTU gas at 20% to 50% above the cost of similar engines for other applications. Gas turbines require cleaning and drying the gas to strict standards to avoid premature failure.
4. Supply is less reliable than public utilities. End-users that have 24 hour per day, 7 day a week production schedules and integrated supply chains concern themselves with supply interruptions. Public utilities, particularly natural gas suppliers, have a history of strong reliability through redundant systems. Concern that a private, stand-alone supply and delivery system will be less reliable is a drawback for end-users.
5. A long-term commitment to purchase gas is required. Thus end-users must be confident that their operations will continue at levels that will require the gas quantity they are committing

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<sup>22</sup> U.S. Department of Energy. Methane Biogas from Digesters (2003).

<http://www.eere.energy.gov/consumerinfo/factsheets/ab5.html>

<sup>23</sup> Applied Filter Technology. The Siloxanes. <http://www.appliedfiltertechnology.com>

too. Gas contracts, discussed in the next section, normally have “take or pay” provisions to assure revenues for the gas supplier.

6. Despite digester gas’s renewable energy status, end-users have concern over bad publicity from the potential perception by their customers that solid waste or manure-sourced gas could somehow carry over into facilities or products being produced from the digester gas. While this notion is counter-intuitive considering traditional fuel sources are fossil fuel based and more environmentally offensive, companies have had to deal with public perception-issues on other baseless notions. This experience has made companies highly sensitive to negative publicity, despite seemingly irrational sources of concern.
7. Risk that no economic savings will be realized in the event that the price of traditional fossil fuels decrease to levels at or below the committed price for digester gas.

### Potential End-Users of the Methane Gas

Utilizing the gas pipeline infrastructure outlined above, the base case for this feasibility study includes having the LLMPC sell its gas output to ZFS and NANR priced at a point of receiving at the proposed new site. This base case assumes the LLMPC will be located at or very near NANR’s facility on the northwest corner of Adams Street and 56<sup>th</sup> Avenue, allowing the methane to be piped to NANR’s facility. ZFS and NANR will then clean, dry, compress, and transport the gas through its pipeline system and deliver it to steam and/or electricity demand hosts. This structure would provide LLMPC assurance that the gas can be sold at firm pricing for assured revenue. In the event that electric generation is used to realize revenue for the methane, ZFS and NANR are able to integrate the capital and operational requirements of electric generation with their existing operations, simplifying the capital and operational requirements at the anaerobic digestion system level.

Five potential end-users have been identified near the end of the pipeline to utilize the methane gas as summarized below:

<u>Company</u>	<u>Use</u>	<u>Level of Interest</u>
Herman Miller	Green Power	Low
Mead Johnson	Steam	Low to Moderate
Zeeland Board of Public Works	Green Power	Low to Moderate
Zeeland Community Hospital	Green Power & Hot Water	Low
Zeeland Farm Services, Inc.	Combined Steam & Green Power	High

Herman Miller is an office furniture manufacturer with headquarters and manufacturing facilities in Zeeland Michigan. The company values green energy initiatives and conservation of energy. Along with those values, Herman Miller desires to operate using green power if available at reasonable prices. Their level of interest in the LLMPC gas is low due to the cost-efficient availability of green power certificates allowing the green power environmental attributes to be separated from actual electric generation. The complexity, capital, and administration required to participate as a user of LLMPC gas also appears to be a deterrent to Herman Miller’s interest.

Mead Johnson is a manufacturer of powdered baby food with a facility located in Zeeland Michigan. Mead Johnson has a low to moderate level of interest.

Zeeland Board of Public Works (ZBPW) is the municipal provider of water and electricity in downtown Zeeland and neighboring areas. ZBPW could utilize the gas to generate base supplies of electricity for its customers. ZBPW's level of interest is low to moderate because it has economical access to wholesale electricity at rates below the renewable energy/green power rates outlined in Scenario #1. Historically it appears that ZBPW's customers are not willing to pay a premium for green power to cover higher electric prices. This may change in the future.

Zeeland Community Hospital is a non-profit hospital/health care provider in Zeeland. It is building a new facility on the east side of Zeeland that theoretically could utilize LLMPC gas to generate electricity and hot water. Due to relatively high additional infrastructure costs required to use gas, relatively low heat requirements, and reasonable current electric prices for high load factor users, the hospital's level of interest in converting to renewable gas from LLMPC is also low.

Zeeland Farm Services, Inc. (ZFS), described in the previous section, is a potential end-user with a high level of interest. ZFS is a user of significant amounts of steam and electric on a steady, 24 hour a day 7 days per week basis in its soybean and soybean oil processing divisions. While its current steam needs are being met from renewable landfill gas, it is also in the final stages of installing electric generation that will run on low-BTU landfill gas. This and future additional electric generation could include self-generating for ZFS consumption or generation of green power to be sold on the electric grid.

Historically, Michigan has had barriers built up preventing green power providers from realizing electric prices that even matched those received by utility generators, let alone provide a premium for renewable green power. This unreasonable historical environment is starting to change. The Michigan Public Service Commission (MPSC) has encouraged Consumers Energy (CE) and Detroit Edison (DTE) to further the percentage of their power derived from renewable energy. Stopping short of a mandated portfolio percentage as issued in other states, the MPSC has used more indirect approaches to make it in the best interests of CE and DTE to procure more of their power from renewable sources. The implied goal is to increase the percentage of Michigan's electric sourced from renewable energy to increase from less than 2% today to a level in the 4% to 7% range over the next decade. These MPSC goals for Michigan mirror national goals as suggested by Congress as well and other state's legislatures.

In summary, the most likely end market for LLMPC gas includes generating green power at ZFS's site due to the infrastructure already in place and familiarity with low-BTU gas.

#### Contractual Arrangements for Long-Term Methane Gas Sales

Common contractual arrangements for long-term private infrastructure projects are outlined below:

1. Agreement terms vary widely due to their private nature and unique supplier and user requirements.

2. Terms are determined on a case-by-case basis by the parties involved.
3. Total contract periods usually in the 15 to 30 year range due to long-term capital commitments.
4. Methane is priced based on mmBTUs (a measure of energy) rather than SCFs (a measure of air quantity).
5. End-user commonly commits to pay for the methane regardless if it is used on a “Take or pay” basis.
6. Pricing methods
  - a. Fixed for the entire term
  - b. Derived from other energy markets
    - i. Natural gas.
    - ii. Electricity.
    - iii. Combination of natural gas and electricity.
    - iv. Other energy benchmarks, factors specific to the end-user, etc.
    - v. May be a combination of all of the above and vary during different time periods of the agreement.
7. Delivery and measurement methods are well defined.
8. Seller commits to gas quality characteristics. Seller is usually subject to economic ramifications if they are not met. The most common ramification is automatic discounts to the price if the end-user elects to take sub-standard gas.
9. Strength and dependability of the Agreement is only as strong as the parties that sign.
10. The use of bank financing by either party can complicate the terms required in the agreement.
11. In extreme cases, provisions are included to allow one party to assume the other party’s assets in the event of an incurable default.

#### Federal and Michigan Tax Credits/Production Credits for “Renewable” Methane Gas Generated Products

Three broad governmental programs were found that would economically benefit the proposed LLMPC. At the federal level, the Jobs Creation Act of 2004 includes a program to subsidize renewable green power from anaerobic digesters. The program is summarized below:

1. Currently offers a federal income tax credit of \$0.0095 per kWh produced from digester gas.
2. The rate paid per kWh adjusts annually for inflation.
3. To receive the credit, the owner of the electric generation must either have taxable income to offset to benefit from the credit or pursue ways to realize value for the credit by properly selling it to an entity with federal tax liability.
4. The credit is received for 5 consecutive years for whatever electric generation quantities were produced during those 5 years.
5. The 2004 Act required equipment to be in-service by December 31, 2005. In 2005 this deadline was extended through 2007.

The second program, also at the Federal level, was included in the Farm Bill Section 9006 in its Renewable Energy Systems and Energy Efficiency Improvements Program. The 2005 program highlights include:

1. Up to \$11,400,000 for outright grants to projects.
2. Another \$11,400,000 for guaranteed loans to finance projects.
3. Up to \$500,000 per project for renewable energy systems.
4. The program may pay up to 25% of total project costs. This results in the project owners having to provide at least 75% of the total necessary funds.
5. 277 grants were made last year in 26 states.
6. Past recipients include anaerobic digesters, wind generation, and waste heat recovery.
7. Applicants must have less than 500 employees and less than \$20,000,000 in annual sales.
8. The annual application deadline is June 28<sup>th</sup>.

The third program, at the state level, is facilitated through Michigan Economic Development Corporation's (MEDC) NextEnergy Authority. The goal of this program is to promote the research, development, and commercialization of alternative energy through state tax credits and exemptions. The program is centered on relief from property taxes and Michigan's value added Single Business Tax (SBT).

The program 100% exempts the project's personal property from property taxes through 2012. Personal property includes equipment and most other project related assets except real property such as land and buildings. The SBT relief reverses the usual Michigan taxation of wages, employee benefits, interest, and portions of capital expenditures. These business expenses must normally be added back to federal taxable income for SBT purposes and then taxed at a 1.9% Michigan tax rate. Approval from the NextEnergy Authority minimizes this SBT to allow the project to avoid this customary SBT.

### Bibliography

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2. Consumers Energy Green Generation Program. [www.consumersenergy.com/green](http://www.consumersenergy.com/green).
3. USDA Rural Development (March 2005). <http://www.FarmEnergy.org>.
4. Michigan NextEnergy Authority Certification Guidebook. (June 2003) [www.michigan.org](http://www.michigan.org).

### **B. Digestate**

FBA analyzed the effluent value only as treated. Untreated effluent is effluent straight from the digester process. Treated effluent is digestate sent through a wastewater treatment system, which cleans the water through various filtration processes in order to make the material suitable for disposal and to meet permit requirements. This water treatment process can remove moisture from the effluent, but very little of the nutrients if properly handled.

Most of the value in the effluent is in the nutrients and there are two uses that give the product its value: as a land applied fertilizer, or for use as compost or bedding material. Depending on the technology used, the liquid component of the digestate could also have potential value as a land applicant, although disposal of the liquid effluent is not a workable solution to the problem of manure disposal in West Michigan.

### Fertilizer Value

A 100,000 gallon per day digester operating with 4% total solids will produce approximately 821,700 lbs of digestate (this is equal to the total influent, less the volatile solids used for generation of the methane). This digestate material is approximately 2% to 3% total solids. If a solids separation unit removes the wastewater, the remaining digestate is assumed to have a solid content of 35%. This gives 71,143 lbs per day of digestate, and 750,557 lbs per day of wastewater. With a 35% total solids content in the digestate there are 24,900 pounds of total solids in the digestate: approximately 1/3 of this will be volatile solids, and the other 2/3 non-volatile solids (the non-volatile portion equals approximately 16,600 lbs each day).

Most of the non-volatile solids are comprised of the nitrogen, phosphorus, and potassium that give fertilizer its value, expressed as an “NPK Ratio.” The N represents the total nitrogen in the fertilizer, while the P and K represent total  $P_2O_5$ , and total  $K_2O$ , respectively.

FBA made the following assumptions during the analysis of fertilizer value of digester effluent:

<b>Table 25: Nutrients Produced from Swine Manure</b>	
	Quantity Produced per 1,000 gallons of swine manure <sup>24</sup>
Nitrogen	48.60
$P_2O_5$	49.80
$K_2O$	31.40

Using these assumptions, a 100,000 gallon digester influent will include approximately 4,860 lbs of N, 4,980 lbs. of  $P_2O_5$ , and 3,140 lbs. of  $K_2O$ . Assuming there is some loss of nutrients during solids separation and treatment equal to 5%, this leaves 4,617 lbs of N, 4,731 lbs. of  $P_2O_5$ , and 2,983 lbs. of  $K_2O$  per day.

Estimates for the replacement value of nutrients vary considerably. The data below shows the average fertilizer cost per pound from five fertilizer dealers contacted by Charles Gould of Michigan State University Extension (three of these dealers are in Allegan County, two are in Ottawa County).

<b>Table 26: Nutrient Fertilizer Replacement Value Estimates</b>					
Fertilizer Dealer	Urea	28%	DAP	MAP	Muriate of Potash (white)

<sup>24</sup> Lorimor, J. (2000). Manure Management Systems Series: Manure Characteristics. MWPS-18, Section 1.

	\$/T	\$/lb N	\$/T	\$/lb N	\$/T	\$/lb P <sub>2</sub> O <sub>5</sub>	\$/T	\$/lb P <sub>2</sub> O <sub>5</sub>	\$/T	\$/lb K <sub>2</sub> O
1	392	0.43			311	0.17			249	0.21
2	408	0.44	234	0.42	343	0.20			259	0.22
3	384	0.42	235	0.42	300	0.16			250	0.21
4	390	0.42					410	0.31	285	0.24
5	290	0.42					355	0.25	275	0.23
Average		<b>0.43</b>		<b>0.42</b>		<b>0.18</b>		<b>0.28</b>		<b>0.22</b>

FBA has assumed the lowest value in each series of data points (highlighted above): N at \$0.42/lb, P<sub>2</sub>O<sub>5</sub> at \$0.16/lb, and K<sub>2</sub>O at \$0.21/lb. These numbers were derived from fertilizer costs supplied by the five fertilizer dealers in Allegan and Ottawa Counties<sup>25</sup>.

<b>Table 27: Estimated N, P, K value of Treated Digester Effluent</b>
4,860 lbs. N X \$0.42/lb = \$2,041.20/day = \$714,420/year
4,980 lbs. P <sub>2</sub> O <sub>5</sub> X \$0.16/lb = \$796.80/day = \$278,880/year
3,140 lbs. K <sub>2</sub> O X \$0.21/lb = \$659.40/day = \$230,790/year
<b>Total Estimated NPK Value: \$1,224,090/year</b>

This estimate assumes the information from MWPS-18, Section 1 is correct, which gives N, P, and K content per 1,000 gallons of swine manure. Accurate estimates can only be determined by testing the regional swine manure to be utilized in the proposed anaerobic digester.

There are 71,143 lbs. of treated digestate produced each day (35.5715 tons/day, or 12,450 tons a year). This digestate is composed of the NPK at 65% moisture, and would be suitable for use as a fertilizer. The estimated value for the treated digestate's use as a fertilizer based solely on its replacement nutrient value is **\$98.32 per ton** (\$1,224,090 ÷ 12,450).

If the digestate is not treated using solids separation, the material will be about 3% solids and 97% moisture. This material would find use as a liquid fertilizer for the producers if sufficient land could be found. Typically, land application rates allow 3,000 to 4,000 gallons be applied per acre at a cost of approximately \$0.01 per gallon—more at distances greater than a mile. The total untreated digestate (which is 3% solids) totals about 98,643 gallons, which would be applied to 25 acres or more a day. Iowa State University estimated \$0.0013 per gallon per mile commercial hauling charges for distances greater than one mile. This hauling charge is driven by a fixed per load cost for the time to load and unload plus a per mile cost to cover operating the truck.

### Compost/Bedding

FBA contacted four composting operations as potential bidders for the digestate material to determine their interest level in utilizing the digestate in their operation for a potential business venture with the LLMPC. A summary of their responses is shown below:

<sup>25</sup> This reference was used to derive fertilizer costs: Barbarick, K.A., and Westfall, D.G. (2004). Fertilizer Cost Calculations. Colorado State University Cooperative Extension. No. 0.548. December 10, 2004.

**Green Valley Agricultural.** John Christian indicated that GVA's interest may be in picking up the digestate. They are currently picking up digestate from a dairy operation, which is splitting the pickup costs with Green Valley Ag. FBA expects that GVA would be interested in pursuing such an option with West Michigan's digester project as the project moves closer to commercialization.

**Renewed Earth, Inc.** Shawn Miner, of Renewed Earth, initially showed great interest in utilization of digestate in Renewed Earth's composting operation. However, Mr. Miner subsequently indicated that Renewed Earth, Inc. has excess organic materials and therefore is not interested in additional organic material from the anaerobic digester at this time.

**Compost Soil Technologies.** This operation is in Zeeland, Michigan. FBA spoke with Tom Turner of CST, who indicated a strong interest level in utilizing the digestate, assuming the economics proved feasible. CST would charge a tip fee to handle the material, and would need to provide bulk materials mixed with the digestate (e.g., wood chips). Compost Soil Technologies proposed two pricing structures for processing the manure:

1. The composting operation is located on a site shared with the digester. The estimated delivery cost per year would be \$87,600. The material would require a liquid waste container and a permit to haul it. CST currently accepts other waste products similar in liquid quantities to swine manure.
2. The manure digestate is brought to the composting site and processed. This would require 8 to 10 acres to operate, graded and sloped, installation, road beds, and other improvements. The estimated capital cost is \$890,000.

The processing cost is the same for both scenarios: \$168,000 per year for 16,000 yd<sup>3</sup> of incoming material, or approximately \$13 per ton. Revenue would depend upon market price; a market value of \$3.50 to \$4.25 per yard would be needed to move the material out.

**JR Huyge Associates.** John Huyge stated that his company's interest might lie in taking the treated digestate material if it were the appropriate solids content (35%). The material would be composted in a static pile or windrow to generate products for horticultural or gardening. Additionally, some of the treated wastewater from the water treatment operation could be used to dilute a portion of the 35% solid digestate to generate biostimulants, another product offered by JR Huyge. The total quantity potential is estimated at 20,000 to 50,000 yd<sup>3</sup> per year. Such an operation would require a large area of land (10+ acres), in addition to capital outlay for equipment to turn the material to allow the composting to occur. Another issue is that the material should remain consistent in order to produce a similar compost product, so there should be little variation in the digester effluent and a comparable nutrient content. The composting operation requires carbon sources, which could be provided via wood chips or the refuse from local furniture operations.

JR Huyge Associates employs aerobic static pile technology to produce the compost used in their soil mixes and biostimulants. They do this for several reasons:

1. The compost takes up less space than windrow operations where 'turning' the windrow is the primary means of maintaining an aerobic condition;

2. The windrow in static pile composting is covered, thus preventing the leaching of the nutrients and maintains more consistent moisture throughout the windrow resulting in more thorough stabilization of the organics, producing more consistent high quality compost;
3. Reduced land, equipment and personnel costs.

To compost the projected volume of digestate generated at the proposed facility, R. Huyge Associates prepared the following scenario. John Huyge indicated there are many variables that cannot be fixed until the project is further developed. Below is reprinted an email response from Mr. Huyge:

“Assuming that the digestate has minimal carbon value we will have to raise the carbon to nitrogen value to achieve good composting. A C:N ratio of 15:1 to 30:1 is targeted, with moisture content of 40-65%. In addition, porosity will be introduced to facilitate ventilation.

“To adjust the C:N, numerous feedstocks are useful and readily available, i.e.: yard waste, shredded paper and corrugated, sawdust and source separated MSW. The moisture content and C:N of these feedstocks will vary widely based on the origin and method of collection. The volume needed will change with the mix of feedstock's available and it is likely that more than one of these feedstocks will be necessary to dispose of the projected volume of digestate. Therefore it is difficult to give firm figures, but based on our experience here is a scenario that will work.

“To dispose of 8,571 gallons of digestate per day:

Feedstocks: 200 cubic yards/day (includes digestate)

Porosity: 50 cubic yards/day

Volume windrowed: 250 cubic yards/day

Land requirement: 1-windrow 250'LX8'WX6'H, necessary area 275'X15' per windrow, recommended site capacity 90 days, proposed compost site acreage, **10 acres**.

“Processing costs will vary with the purity, texture and moisture content of the feedstocks. Clean sawdust, wood chips shredded paper or corrugated require no premix grinding to achieve uniform texture and can be mixed, windrowed, covered and managed for about \$10 to \$12 per cubic yard windrowed. If yard waste or source separated MSW (municipal solid waste) is used, processing costs will be \$15 to \$20 per cubic yard. NOTE: Clean sawdust, wood waste and shredded paper have secondary market value and may have to be purchased; the cost savings of processing will need to be balanced against the expense of the commodity. Yard waste and source separated MSW have higher processing costs but may generate income through tipping fees, this may effectively offset a portion of the processing cost.

“Compost product value fluctuates based on supply, quality and local market. In the southwest Michigan market similar quality products sell for **\$25 to \$30** per cubic yard. Introducing this volume of product in this market could reduce its selling price initially. The harvest, based on feedstocks used will reflect volume reduction of 20-30%.”

Note: Bolded comments in the last paragraph were bolded by FBA, not Mr. Huyge.

FBA analyzed the potential increase in value of the digestate through composting. Composting the digestate would involve the West Michigan LLMPC setting up a profit-sharing venture with a composting operation. A benefit of composting the digestate would be to reduce the total volume of material that requires handling through the drying/composting of the digestate.

A full economic analysis of composting is beyond the scope of this report; however, discussions with composting operations indicate the following overall requirements for this operation:

- Mixing the digestate with “bulking” agents such as wood chips to increase the carbon to nitrogen ratio of the digestate to aid in composting
- 10 or more acres for spreading and windrowing the compost
- Equipment to handle the compost

Assuming J.R. Huyge’s cost estimates are accurate, the value of the composted product will be \$25 to \$30 per cubic yard. A ton of digestate at 35% solids content will yield, after introducing bulking agents and given time for composting, approximately 175 cubic yards per day (this equates to approximately 0.28 cubic yards per ton of digestate). The estimated operating costs for composting a cubic yard are summarized below:

<b>Table 28: Composting Operating Costs Per Yd<sup>3</sup></b>	
	<b>Cost/yd<sup>3</sup></b>
Gross Revenue	\$25
Cost to Compost:	
Bulking Agents	\$14
Site Preparation	\$3
Maintenance	\$3
Cost to Compost	- \$20
Net Revenue per Yd <sup>3</sup>	\$5

The revenue estimate is provided by J.R. Huyge, who stated \$25 to \$30 per yd<sup>3</sup>, depending on what the market will bear. FBA assumed the low end of this value range. Bulking agent costs include all materials for increasing the carbon content of the material, and including mixing and/or blending of materials. Site preparation is spreading of the material; maintenance is the required temperature monitoring and turning of windrows. This estimate does not include the cost for site procurement (10 acres), or capital costs for the equipment to handle/turn the compost.

The net revenue is to be split between the digester and the composting operation. If there was a direct 50%/50% to West Michigan LLMPC, the revenue per cubic yard to the digester would be \$2.50. At 175 yd<sup>3</sup> per day, this equates to \$153,125 per year of revenue, considerably less than the \$1.7 million in revenue from sale of the 35% solid digestate. Even if West Michigan LLMPC were to retain 100% of the revenue stream (\$5 per yd<sup>3</sup>) the annual revenue would be approximately \$300,000 from the sale of compost.

Based on this preliminary analysis FBA sees no value in the composting of the digestate as a revenue stream to the digester. To a composting operation, this might be a viable opportunity if no additional equipment is to be purchased (using existing infrastructure) and if the material could be delivered consistently and at no cost.

Note: These are estimates made by FBA with the information available. An expert in composting (such as Ron Alexander of R.A. Associates) should be consulted for an independent and more accurate cost estimate for this operation.

### **C. Other Marketable Products from Anaerobic Digestion**

#### **Fuel Pellets**

Demand for corn burners and wood stoves have increased due to skyrocketing heating costs. Demand for fuel to burn in these stoves has also increased.

The current West Michigan price for a cord of wood is around \$139/cord (Range: \$129-\$150/cord; Source: Jeff's Firewood and Logging, Twin Lake, MI and Lawn Maintenance and Snowplowing, Muskegon, MI) and \$1.85 for a bushel of corn (January 2006 price according to [www.zfsinc.com](http://www.zfsinc.com)).

A bushel of No. 2 yellow shelled corn weighs 56 pounds at 15.5% moisture. It is estimated that the average home, depending on how well it is insulated, will burn 200-250 bushels of corn per year<sup>26</sup>. A homeowner can expect to burn about three tons of pellets a season<sup>27</sup>.

Although the chemical constituents and moisture content of different biomass materials vary, the Pellet Fuel Institute has identified common characteristics and developed fuel standards. These voluntary industry standards assure as much uniformity in the final product as is possible for naturally grown materials that become processed, but not refined fuel. PFI graded fuel must meet tests for:

- Density: consistent hardness and energy content (minimum 40 pounds/ cubic foot).
- Dimensions: length (1 1/2" maximum) and diameter (1/4" or 5/16") to assure predictable fuel amounts and to prevent fuel jamming.
- Fines: limited amount of sawdust from pellet breakdown to avoid dust while loading and problems with pellet flow during operation (amount of fines passing through 1/8" screen no more than 0.5% by weight).
- Chlorides: limited salt content (no more than 300 parts per million) to avoid stove or vent rusting.
- Ash content: important factor in maintenance frequency.

Fuel Pellet Retail Prices:

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<sup>26</sup> [www.ja-ran.com/superior.php](http://www.ja-ran.com/superior.php)

<sup>27</sup> [www.treehugger.com/files/2005/10/wood\\_pellet\\_sto.php](http://www.treehugger.com/files/2005/10/wood_pellet_sto.php)

- Premium pellets: (less than 1% ash, 0.5% fines, and 300 ppm sodium) \$198.00 per ton plus \$65/ton delivery charge (\$263/ton) Source: <http://www.woodfuelpellets.com/>
- Premium sawtooth pine pellet, \$187/ton. Source: [www.pelletheat.org/3/industry/retailersOnly.cfm](http://www.pelletheat.org/3/industry/retailersOnly.cfm)
- Lowe's of Holland, MI (Vulcan Wood Products, Marshfield, WI): Premium pellets: \$2.40/50# bag or \$96/ton

According to Aaron Equipment (Chicago, Illinois), used equipment is very hard to come by because of the demand for wood pellets. The price range for a complete used pelletizing system was estimated to range from \$75,000-\$100,000 for a 50 to 70 hp system, to \$200,000-\$300,000 for a 300 hp system. Leistritz Extruder Corporation estimated that a new system could cost up to \$750,000.

#### Other Potential Co-Products:

- Composite material (medium density fiberboard and plastic wood)
- Currently a pilot project is funded at Michigan State University to make both medium density fiberboard and plastic wood from the fibrous digestate material. This same study will also provide information that will be helpful in pellet production.

#### Carbon Credits

##### **Purchase Price for Carbon Credits**

As of January 19, 2006, a metric ton of CO<sub>2</sub> was selling for \$1.65.<sup>28</sup> Historical price data shows that CO<sub>2</sub> has fluctuated between \$1.80 per metric ton (December 1, 2005) to the current price referenced above.

##### **Value of Carbon Credits**

Carbon dioxide weighs 0.12342 lbs/ft<sup>3</sup>. A digester producing 40,000 mmBTU's per year would generate 72,727,000 ft<sup>3</sup> of gas. Estimating that 40% of the volume of gas is CO<sub>2</sub> there is 29,090,800 ft<sup>3</sup> of CO<sub>2</sub>. Thus, 1,628 metric tons per year of CO<sub>2</sub> is generated (29,090,909 divided by 17,866). At \$1.65/metric ton this equals \$2,686 in revenue.

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<sup>28</sup> [www.chicagoclimateexchange.com](http://www.chicagoclimateexchange.com)

## VI. Project Financial Analysis

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### A. Basic Assumptions and Information

These assumptions and general information are to be a supplement to the financial projections included in the Addenda for the West Michigan Anaerobic Digestion feasibility study. The information provided in this discussion does not include all of the assumptions that were made in preparing the projected financial report. The included and non-stated assumptions are based on Frazier, Barnes & Associates' judgment at the date of preparation. The projections were prepared in April 2006. This projected financial report is intended to present an illustration of the potential financial situation for a 100,000 gallon per day anaerobic digester in West Michigan. These projected results may differ considerably from actual operating results, due to many unforeseen events and circumstances. The information provided in each case does not necessarily show the worst, best or average possible prices. The projections are intended to indicate the degree of associated variability possible with the different feedstock and product price scenarios. This projected financial report is intended for the use of informing potential investors and lenders of the possible benefits or risks of their investments, and should not be used for any other purpose.

### B. Loan Assumptions

1. **General Information:** It is assumed that 50% of the project's capital cost requirements will be financed through a bank. At this point in the project there is not a financing package or lending institution that has agreed to be involved. For ease of creating these projections, it was assumed that the entire debt would be financed through one institution, at one interest rate and repayment term.
2. **Interest Rate:** This rate is a conservative estimate of the interest rate that the project would be able to receive from lenders. This is not a set rate, only an estimated one. There have been no negotiations with financial institutions at this point and the actual rate received most likely will vary some from the stated rate in these projections. The rate used is 8.0%.
3. **Term:** The Term is the number of years that the debt is expected to be financed over. No negotiations have been made at this point and the actual term of the debt can be determined later by the group of investors and the lenders involved. This model uses a 10 year term.
4. **Principal:** This is the original amount of the debt. This is assumed to be 50% of the total project cost.
5. **Payment:** This is the calculated annual payment, considering the above assumptions. This is not a definite amount and the precise payment would depend on the negotiations that are actually made and the terms of the debt that are agreed upon. FBA has assembled the accompanying projections and assumptions for the West Michigan LLMPC for the first ten years. The forecasted financial information omits the summary of significant accounting policies and does not indicate which of the disclosed assumptions included in the summary of significant assumptions are particularly sensitive to changes. Furthermore, differences between the forecasted and actual results can be expected because events and circumstances frequently do not occur as forecast.
6. **Useful Life:** The useful life of the anaerobic digester is assumed to be 15 years, with \$0 salvage value at the end of its useful life.

7. **Inflation:** All proforma estimates for variable expenses use an inflation factor of 2% increase per annum.
8. **Taxes:** No accounting for taxes has been made in the financial projections. All returns on equity are based on the net operating income before taxation (EBIT).
9. **Depreciation:** Straight-line depreciation was utilized in the pro forma, with 15-year for Property Plant & Equipment (PP&E).
10. **Expenses:** Some vendors were unable to supply estimates for some expenses. FBA assumed the following additional expenses, unless these expenses were included in the technology supplier's quotation:

Engineering:	5% of PP&E
Management & Training:	2% of PP&E
Labor	2% of PP&E
Site Preparation:	8% of PP&E
Miscellaneous Startup Costs:	10% of PP&E

Proforma were derived using as much information that could be obtained from the technology provider as possible. Where information on operating expenses was lacking, FBA made assumptions to ensure all suppliers were given a relatively equal baseline for analytical purposes. Other assumptions used in the Financial Analysis:

- Methane gas revenue to the digester facility of \$3.35 per mmBTU. This price has not been set and is only an estimate.
- Digestate value (35% total solids) is \$35 per ton
- Because swine producers are resistant to paying a tipping fee for delivery of manure to the facility, the Base Case assumes there is a \$0 tipping fee.
- An additional expense was assumed for insurance and for taxes equal to 1.5% of total capital.
- FBA added a 15% contingency to the capital cost of each digester technology. This contingency accounts for fluctuations in capital costs due to time lags in initial quotes versus costs of construction at a future date.
- Additional operating expense for sales, general and administrative costs equal to \$0.002 per gallon is assumed.
- Land space requirements vary with the technology and footprint required; an expense of \$100,000 for land was assumed.
- Depreciation uses the straight-line method and only the capital expenses were used for the depreciable basis (i.e. land and interest are not included in depreciation).
- Depending on the specific digester and various conditions, it may take some time for the digester bacteria population to grow to maximum. The first year of operation is assumed at 75% of plant capacity.
- Bulk density of swine manure of 9 lbs per gallon. The actual density of swine manure varies with the solids content in the manure, and the composition and density of those solids. If the actual bulk density of the manure is higher than 9 lbs per gallon there will be an increase in methane generation and digestate material over what is shown in the summaries in this study.

- Because the primary goal of this project is to find an alternate method of disposing of liquid manure wastes, the digestate material should be as dry as possible. Two of the digester technology providers who supplied quotations for this report had no solids separation or drying of digestate, so the digestate was very high in moisture (approximately 98%). A solids separation unit was added to these two technologies to produce a digestate relatively similar in quality for valuation purposes. This cost for a solids separation unit is estimated at \$750,000, including installation.

### C. Project Financial Analysis

The primary factors that are being analyzed in the financial analysis section of this report are:

- Digester Feedstock Requirements and Cost
- Anaerobic Digester Capital Costs (Equity and Financing)
- Anaerobic Digester Operating Costs
- Anaerobic Digester Methane Gas Yields and Values
- Co-product Yields and Values

A financial analysis was performed for the return on investment for the proposed West Michigan anaerobic digester facility. The financial model for each vendor analyzed was based on the following assumptions:

Table 29: Project Financial Assumptions	
Category	Assumption
Swine manure Feedstock	100,000 Gallons/Day (Base Case)
Feedstock Cost	\$0.00, Delivered to the Facility
Total Solids Content	4%
Total Volatile Solids Content	2%
Operating Days/Year	350 Days/Year
Interest Rate	8.0%
Amortization	10 Years
Other Assumptions	No grants nor other financial incentives

Since there is uncertainty about the quantity of solid-boosting material that will be available for the project, FBA asked the vendors to provide base-line information for 100% swine manure digestion, with the additional request to treat the digestate material in order to provide water disposal. This is the **Base Case** model used in the analysis: The collection and anaerobic digestion of 100% swine manure material. This assumes swine manure is the only waste delivered to the proposed central processing facility. Additional models take advantage of the potential increase in biogas production with an increase in the solids content. Volatile Solids are the source of the biogas generated during anaerobic digestion. Because swine manure alone provides only 2% of the volatile solids of the influent stream, the digesters are capable of handling a greater quantity of volatile solids. As the volatile solids increases, the biogas produced is also increased. This is the benefit of the additional models used in the Sensitivity Analysis to follow.

The base case financial summary assumes 100% swine manure is used as an influent, with no additional feedstocks added to the digester. The assumption is that additional feedstocks are either unavailable, or their cost for inclusive is prohibitive.

NOTE: Applied Technologies were also contacted by FBA for a preliminary budget estimate for this project. This information was requested primarily as a check against the capital costs for the other four systems, for comparison purposes, because there were concerns the technology estimates were too high. At the time this report was finished (April 24, 2006) FBA was still trying to obtain more detail from Applied Technologies related to operating costs and methane generation. Because this data was not complete, it is not included in the financial analysis discussion. It should be noted the capital cost for the Applied Technologies anaerobic digester was estimated at \$4.6 million.

A summary of the other four technology suppliers is shown below:

<b>Table 30: Summary of Financial Analysis Base Case (100% Swine Manure @ 4% TS)</b>				
	Waste Energy Solutions*	RCM-Biothane	Andigen	Biopower Technologies
Swine manure	100,000 Gallons			
Total Solids in Influent Stream	4.0%			
Capital Cost	\$12,478,363	\$6,353,750	\$4,581,232	\$3,744,259
Methane Volume	43,933 mmBTU	40,850 mmBTU	36,681 mmBTU	32,798 mmBTU
Methane Revenue	\$147,176	\$136,846	\$122,880	\$109,873
Liquid Digestate	11,300 Acres			
Solid Digestate	10,500 Tons	13,500 Tons	13,500 Tons	13,500 Tons
Digestate Value	\$549,000	\$472,500	\$472,500	\$472,500
Internal Rate of Return	< 0%	< 0%	-4.7%	-1.2%
ROI	-11.6%	-11.3%	-5.7%	-1.1%

\* WES indicated its digester could not operate with 100% swine manure as an influent, and would require some carbon sources as boosting agents. This summary is shown for illustration and comparison purposes.

The result of the Base Case is clear: none of the projects will perform using only swine waste as a feedstock. Total solids content has the greatest impact on availability of volatile solids for methane generation and on the total digestate material produced. At this level the revenue from digestate sales is approximately four times that of methane. The returns on investment for all technologies are below zero. A 100% swine waste anaerobic digester is not a financially attractive model without financial incentives or tipping fees for handling of the waste.

Additional analysis is necessary to determine a viable scenario that will make the project work, financially. This approach involves adding higher solid content feedstocks to swine waste in order to increase the total solids (and volatile solids) entering the digester. This allows an increased

methane generation (because of the increased volatile solids), and additional digestate material generation (since a higher total solids indicates there will be a higher quantity of solids available in the digestate effluent).

#### **D. Sensitivity Analysis**

FBA performed a number of sensitivity analyses on the four digesters for various mixtures of influent wastes.

Typical projects of this size and scope require a minimum return on investment of 15% or higher to secure financing; FBA will not recommend a technology that shows less than a 15% preliminary return. Additionally, lenders will “stress test” proforma for sensitivity to returns. FBA has simulated this stress testing with a Sensitivity Analysis to determine how sensitive the Return on Investment (ROI) is to fluctuations in methane value, delivery costs for the feedstocks to the digester, solids in the manure, and the value of the semi-solid digestate.

The Sensitivity Analysis includes six scenarios:

- **Test 1 - Swine Manure and Swine Mortality:** This case adds 713 tons a year of regionally available swine carcasses to increase the total solids content of the influent stream. Swine mortality is delivered to the facility at zero cost and does not provide any tipping fee revenue to the facility. The purpose of this test is to see the impact of adding mortality on the methane generation.
- **Test 2 – Swine Manure with Swine Mortality and Deer Mortality.** This case adds 140 tons a year of deer mortality to see what benefit this additional quantity of mortality adds to the previous test.
- **Test 3 – Swine Manure with Offal.** This test analyzes the Base Case with the addition of offal and slaughterhouse waste.
- **Test 4 – Swine Manure with Mortality and Offal –** All mortality (swine and deer) is now added to Test 3 to see its impact on biogas production.
- **Test 5 – Swine Manure Only - 10% Total Solids.** This tests the increased biogas output of a digester with a higher total solids content in the manure. The base case uses 4% total solids, which assumes flushed swine manure. This tests the results of a digester performing at higher solid levels in the swine manure.
- **Test 6 – Swine Manure with Corn Silage.** This scenario assumes corn silage could be delivered at \$0 per ton. Swine manure is analyzed at 4% total solids for this scenario (base case).

Note: The mortality tests are included for illustration purposes only. Michigan currently does not allow disposal of mortality or offal through anaerobic digestion. These scenarios were included to forecast returns in the event the law changes.

The results of these tests are summarized below.

<b>Table 31: Summary of Financial Analysis</b>				
<b>Test 1: Swine Manure and Swine Mortality</b>				
	Waste Energy Solutions	RCM- Biothane	Andigen	Biopower Technologies
Swine manure	99,547 Gallons/Day			
Swine Mortality	713 Tons/Year			
Total Solids in Influent Stream	4.14%			
Capital Cost	\$12,478,363	\$6,353,750	\$4,581,232	\$3,744,259
Methane Volume	49,482 mmBTU	44,502 mmBTU	40,523 mmBTU	36,487 mmBTU
Methane Revenue	\$165,765	\$149,081	\$135,752	\$122,230
Liquid Digestate	11,300 Acres			
Solid Digestate	10,500 Tons	13,974 Tons	13,974 Tons	13,974 Tons
Digestate Revenue	\$549,000	\$489,077	\$489,077	\$489,077
Internal Rate of Return	< 0%	< 0%	-3.7%	0.2%
ROI	-10.8%	-10.4%	-4.4%	0.4%

<b>Table 32: Summary of Financial Analysis</b>				
<b>Test 2: Swine Manure, Swine Mortality, Deer Mortality</b>				
	Waste Energy Solutions	RCM-Biothane	Andigen	Biopower Technologies
Swine manure	99,458 Gallons/Day			
Swine Mortality	713 Tons/Year			
Deer Mortality	140 Tons/Year			
Total Solids in Influent Stream	4.17%			
Capital Cost	\$12,478,363	\$6,353,750	\$4,581,232	\$3,744,259
Methane Volume	50,572 mmBTU	45,219 mmBTU	41,277 mmBTU	37,211 mmBTU
Methane Revenue	\$169,415	\$151,484	\$138,280	\$124,656
Liquid Digestate	11,300 Acres			
Solid Digestate	10,500 Tons	14,067 Tons	14,067 Tons	14,067 Tons
Digestate Revenue	\$549,000	\$492,332	\$492,332	\$492,332
Internal Rate of Return	< 0%	< 0%	-3.4%	0.5%
ROI	-10.7%	-10.2%	-4.2%	0.7%

Tests 1 and 2 added available swine and deer mortality to the influent mix. The result was a small improvement in financial performance, roughly equivalent to an increase of 1% ROI. The total solids increased from 4.00% to 4.17%, a minimal amount.

<b>Table 33: Summary of Financial Analysis</b>				
<b>Test 3: Swine Manure and Offal</b>				
	Waste Energy Solutions	RCM-Biothane	Andigen	Biopower Technologies
Swine manure	80,952 gal	80,650 gal	80,650 gal	88,700 gal
Slaughtering Waste	30,000 tons	30,000 tons	30,000 tons	17,798 tons
Total Solids in Influent Stream (Max Allowed)	9.9%	9.9%	9.9%	7.5%
Capital Cost	\$12,478,363	\$6,353,750	\$4,581,232	\$3,744,259
Methane Volume	237,064 mmBTU	167,583 mmBTU	170,209 mmBTU	108,893 mmBTU
Methane Revenue	\$794,165	\$561,402	\$570,201	\$364,790
Liquid Digestate	11,300 Acres			
Solid Digestate	10,500 Tons	33,428 Tons	33,428 Tons	25,323 Tons
Digestate Revenue	\$549,000	\$1,169,996	\$1,169,996	\$886,292
IRR	< 0%	23.3%	42.3%	33.4%
ROI	-0.9%	23.2%	43.1%	33.7%

Test 3 showed a significant gain in both methane generation and digestate material. The total solids is increased from 4% to 9.9% for three of the technologies using all available offal (the fourth digester, Biopower Technologies, has a capability of handling only 7.5% total solids). These are positive returns for the project. Because of the increase in total solids, the methane and digestate generated is (approximately) tripled over the Base Case scenario of 100% swine manure.

<b>Table 34: Summary of Financial Analysis</b>				
<b>Test 4: Swine Manure, Mortality, Offal</b>				
	Waste Energy Solutions	RCM-Biothane	Andigen	Biopower Technologies
Swine manure	80,640 gal	80,640 gal	80,640 gal	88,708
Swine Mortality	473 Tons/Year			
Slaughtering Waste	30,000 tons	30,000 tons	30,000 tons	16,931 tons
Total Solids in Influent Stream	10.0%	10.0%	10.0%	7.5%
Capital Cost	\$12,478,363	\$6,353,750	\$4,581,232	\$3,744,259
Methane Volume	240,745 mmBTU	170,003 mmBTU	172,756 mmBTU	109,602 mmBTU
Methane Revenue	\$806,497	\$569,510	\$578,731	\$367,166
Liquid Digestate	11,300 Acres			
Digestate Volume	10,500 Tons	33,742 Tons	33,742 Tons	25,314 Tons
Digestate Revenue	\$549,000	\$1,180,981	\$1,180,981	\$885,984
Internal Rate of Return		23.9%	43.1%	33.5%

ROI		23.8%	43.9%	33.8%
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Test 4 differs from Test 3 only by increasing the total solids content from 9.9% to 10%. Therefore all available offal is utilized, along with approximately 473 tons of swine mortality. The result is approximately 0.5% to 1% improvement in returns; i.e. there is little benefit from adding mortality if turkey offal is available. Note that Biopower Technologies already reached a 7.5% total solids limit using offal, and therefore the Test 4 results are the same.

The optimal scenario for all digesters is to maximize the total solids entering the digester. Swine manure alone will not work, as shown previously, since the methane content of swine manure is relatively low.

<b>Table 35: Summary of Financial Analysis Test 5: Swine Manure at 10% TS</b>				
	Waste Energy Solutions	RCM-Biothane	Andigen	Biopower Technologies
Swine manure	100,000 gal	100,000 gal	100,000 gal	75,000 gal
Total Solids in Influent Stream	10.0%	10.0%	10.0%	7.5%*
Capital Cost	\$12,478,363	\$6,353,750	\$4,581,232	\$3,744,259
Methane Volume	109,833 mmBTU	102,124 mmBTU	91,702 mmBTU	75,550 mmBTU
Methane Revenue	\$367,939	\$342,115	\$307,201	\$256,443
Liquid Digestate	11,300 Acres			
Digestate Volume	10,500 Tons	33,750 Tons	33,750 Tons	29,250 Tons
Digestate Revenue	\$549,000	\$1,181,250	\$1,181,250	\$1,023,750
Internal Rate of Return	5.3%	17.0%	32.3%	34.8%
ROI	-2.2%	16.8%	32.3%	35.3%

\* 25,000 gpd of water was added to dilute mixture to 7.5% TS, maximum allowed by this technology; it is assumed that, after initial startup, a portion of the treated liquid wastewater from this digester is used

Test 5 shows the potential increase in returns due to higher solids content in the manure. This scenario includes only swine manure as a feedstock. This is a valuable test that shows a positive return is possible using only manure if the total solids are 10%.

<b>Table 36: Summary of Financial Analysis Test 6: Swine Manure (4% TS) With Corn Silage</b>				
	Waste Energy Solutions	RCM-Biothane	Andigen	Biopower Technologies
Swine manure	76,923 gal	76,923 gal	76,923 gal	86,538 gal
Corn Silage	25,119 tons/year	25,119 tons/year	25,119 tons/year	14,653 tons/year
Total Solids in	10.0%	10.0%	10.0%	7.5%*

Influent Stream				
Capital Cost	\$12,478,363	\$6,353,750	\$4,581,232	\$3,744,259
Methane Volume	133,570 mmBTU	124,071 mmBTU	124,998 mmBTU	82,428 mmBTU
Methane Revenue	\$447,460	\$415,639	\$418,743	\$276,133
Liquid Digestate	11,300 Acres			
Digestate Volume	10,500 Tons	26,533 Tons	26,533 Tons	21,102, Tons
Digestate Revenue	\$549,000	\$928,644	\$928,644	\$738,584
Internal Rate of Return	< 0%	11.4%	26.5%	5.9%
ROI	-6.4%	11.3%	26.3%	6.2%

\* 25,000 gpd of water was added to dilute mixture

The last scenario, Test 6, is a theoretical one that assumes corn silage is available at no cost to the facility. The test shows that in all but one case, even a no cost corn silage feedstock would not be enough of a methane boost to the digester to warrant its use.

Of the four technology suppliers analyzed for this report, Waste Energy Solutions shows consistently poor returns. This technology supplier admitted its capital cost was high, but stood by the performance of the system.

Because the total solids content of the manure is such a critical factor in its performance, and mortality and offal cannot be currently disposed of in anaerobic digester in Michigan, the Base Case scenario is the only viable one open to the project. That is, 100,000 gallons of swine manure delivered to the facility, with no additional feedstocks used. All four technology vendors showed a negative return on investment; Biopower Technologies had the best ROI of the four (at -1.1%). Biopower Technologies is the only one of the four vendors that provided FBA with a method of separating the digestate into a solid stream and a treated, disposable wastewater. This technology also had the lowest capital cost.

FBA performed additional sensitivity analysis on Biopower Technology's anaerobic digester. For this analysis, FBA focused on the value of the biogas, the potential revenues from the collection of the influent wastes (i.e. tipping fee), and the value of the treated digestate.

Because all the technologies showed a negative return, FBA's objective was to determine in the sensitivity tests the optimal performance conditions where the anaerobic digester would give a positive return (15% or higher). The base case assumptions were used as a baseline:

- 100,000 gallons/day swine manure delivered to the facility
- Total solids content of swine manure is 4%
- Digestate value is \$35 per ton

The first sensitivity test is a comparison of natural gas to a tipping fee for delivery of the swine manure to the facility. The base case assumed there was \$0 cost delivery of the manure to the

digester, and the natural gas revenue of \$3.35 per mmBTU. This scenario only analyzes the tipping fee for the swine manure, not the offal.

<b>Table 37: ROI Sensitivity Scenario 1 for Biopower Technologies</b>								
		Swine manure Tipping Fee per Gallon						
		Cost to the Digester (-)			No cost	Fee Paid to the Digester (+)		
±\$1.00		\$0.003	\$0.002	\$0.001	\$0.000	\$0.001	\$0.002	\$0.003
Natural Gas Value per mmBTU	\$0.35	-55.4%	-39.0%	-22.6%	-6.2%	10.2%	26.6%	43.0%
	\$1.35	-53.7%	-37.3%	-20.9%	-4.5%	11.9%	28.3%	44.7%
	\$2.35	-52.0%	-35.6%	-19.2%	-2.8%	13.6%	30.0%	46.4%
	<b>\$3.35</b>	-50.3%	-33.9%	-17.5%	-1.1%	15.3%	31.7%	48.1%
	\$4.35	-48.6%	-32.2%	-15.8%	0.6%	17.2%	33.4%	49.8%
	\$5.35	-46.9%	-30.5%	-14.1%	2.3%	18.7%	35.1%	51.5%
	\$6.35	-45.2%	-28.8%	-12.4%	4.0%	20.4%	36.8%	53.3%

The model is very sensitive to swine tipping fees. Without tipping fees, the value of the biogas must increase from \$3.35 per mmBTU to \$12.75 per mmBTU to reach 15% ROI, an increase of almost 400% in natural gas prices. In fact, the digester can only operate if there is a tipping fee of a tenth of a cent per gallon. It is this \$0.001 per gallon that gives a positive cash flow for the digester (when the swine manure is at 4% TS).

The second test analyzes the sensitivity to the value of the digestate. As is apparent from a study of the financial proforma (included in the Addenda) the revenue from digestate is significantly greater than the potential revenue from the biogas, approximately four times that of the biogas. If the value of the digestate drops there is an expected drop in the return for the project. This scenario looks only at changing digestate and natural gas values; tipping fees are assumed to be \$0 for swine manure.

<b>Table 38: ROI Sensitivity Scenario 4 for Biopower Technologies</b>								
		Digestate Value per Ton						
		\$5	\$15	\$25	\$35	\$45	\$55	\$65
Natural Gas Value per mmBTU	\$0.35	-27.3%	-20.3%	-13.2%	-6.2%	0.8%	7.9%	14.9%
	\$1.35	-25.6%	-18.6%	-11.5%	-4.5%	2.5%	9.6%	16.6%
	\$2.35	-23.9%	-16.9%	-9.8%	-2.8%	4.2%	11.3%	18.3%
	<b>\$3.35</b>	-22.2%	-15.1%	-8.1%	-1.1%	5.9%	13.0%	20.0%
	\$3.60	-21.8%	-14.7%	-7.7%	-0.7%	6.4%	13.4%	20.4%
	\$3.85	-21.3%	-14.3%	-7.3%	-0.2%	6.8%	13.8%	20.9%
	\$4.10	-20.9%	-13.9%	-6.8%	0.2%	7.2%	14.3%	21.3%

What this sensitivity analysis shows is that, without tipping fees, the digestate value must be \$65 per ton to reach 15% returns. The advantage in this higher digestate value is that natural gas can drop \$2.00 per mmBTU and still maintain 16.6% ROI.

The final test analyzes the total solids content of the swine manure versus the digestate value. Because the Biopower Technologies digester can only handle 7.5 total solids, FBA limited the analysis to 7.5% TS.

<b>Table 39: ROI Sensitivity Scenario 4 for Biopower Technologies</b>								
		Digestate Value per Ton						
		\$5	\$15	\$25	\$35	\$45	\$55	\$65
Total Solids Content of Swine	2%	-29.2%	-26.8%	-24.5%	-22.1%	-19.8%	-17.5%	-15.1%
	3%	-25.6%	-21.0%	-16.3%	-11.6%	-6.9%	-2.2%	2.5%
	4%	-22.2%	-15.1%	-8.1%	-1.1%	5.9%	13.0%	20.0%
	5%	-17.8%	-8.5%	0.9%	10.3%	19.7%	29.0%	38.4%
	6%	-14.4%	-2.7%	9.0%	20.7%	32.4%	44.2%	55.9%
	7.5%	-12.7%	2.6%	17.8%	33.0%	48.3%	63.5%	78.7%

This model shows how sensitive the project would be to swings in digestate value and total solids in the manure. A 1% increase in total solids content equates to approximately 10% increase in ROI; similarly, a \$10 increase in digestate value shows a 10% to 15% increase in ROI. If digestate value is \$35 per ton, the total solids content must be approximately 5.5% to reach 15% return on investment. At 4% total solids content, the digestate value must be \$58 per ton to reach the same ROI.

### **E. Financial Summary**

FBA ran several additional scenarios to determine what would be needed to reach a recommended 15% return on investment if 100% swine manure (at 4% total solids) was utilized; i.e. no additional feedstocks were included in the digester:

- A 5.5% total solids content will reach 15% ROI
- At \$35 per ton for digestate, natural gas must be \$12.75 per mmBTU
- At a natural gas price of \$3.35 per mmBTU, the digestate value must be \$58 per ton
- At \$35 per ton for digestate, and natural gas of \$3.35 per mmBTU, a tipping fee of \$0.001 per gallon must be paid to the digester by the producer

If the total solids content in the swine manure was 7.5% instead of 4%, the project (using all other assumptions) would have a 35% return.

A comparison of these sensitivity analyses on a 1% ROI change basis is helpful (i.e., how much of each feedstock or product must change to affect ROI by 1%):

<b>Table 40: ROI Comparison Factors</b>	
	Equivalent Rates
Swine Manure Total Solids	0.1% total solids
Swine Tipping Fee	\$0.0001 per gallon (one-

	hundredth of one cent)
Digestate Value	\$1.50 per ton
Natural Gas Price	\$0.65 per mmBTU

## **VII. Management and Business Structure Analysis**

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### **A. Management Requirements**

To improve the success of the project it must have an on-site manager. The General Manager should clearly understand the goals and objectives of the anaerobic digester from the start. Digesters are highly sensitive pieces of equipment and usually must be monitored since fluctuation in temperatures and pH can result in decreased performance or temporary failure of the digester.

The moisture content of the manure and feedstock mix must be monitored to remain consistency. Management should ensure that feedstock collection is well organized to provide a consistent flow of material for the digester.

Other Management considerations are the safety of the digester. The biogas contains methane (approximately 2/3 by volume) which is highly explosive. Any hydrogen sulfide (H<sub>2</sub>S) left in the gas after desulphurization remains corrosive and dangerous. The system should be designed with proper ventilation and hazard control.

The primary reason anaerobic digesters fail is improper design or installation; second is poor quality equipment; third on the list is digester management<sup>29</sup>. Management must monitor the digester and be familiar in its operation. The General Manager must be well-versed in the technology. Specific time requirements for management are specific to each digester.

### **B. Business Structure Option**

Some possible business structures for the anaerobic digester business include:

- Producer-owned (closed cooperative); the operation is owned and controlled entirely by producers who will supply feedstock for the facility; as a closed cooperative, non-producers cannot invest in the project.
- Privately-held company; the anaerobic digester is owned and operated by a separate company through private investors; feedstock suppliers have no control over the operation of the business and only supply feedstock to the facility.
- Closed coop/privately-held company; a combination of the above two structures, which allows flexibility in granting control to private investors and the suppliers of the feedstock.

The last option is the most attractive. A cooperative is formed, tentatively called West Michigan Renewable Energy, LLC (WMRE), made up of various investors divided into two groups: the West Michigan Liquid Livestock Manure Processing Center Cooperative (formed of growers, producers, and all other suppliers of feedstock to the anaerobic digester), and non-growers and non-producers.

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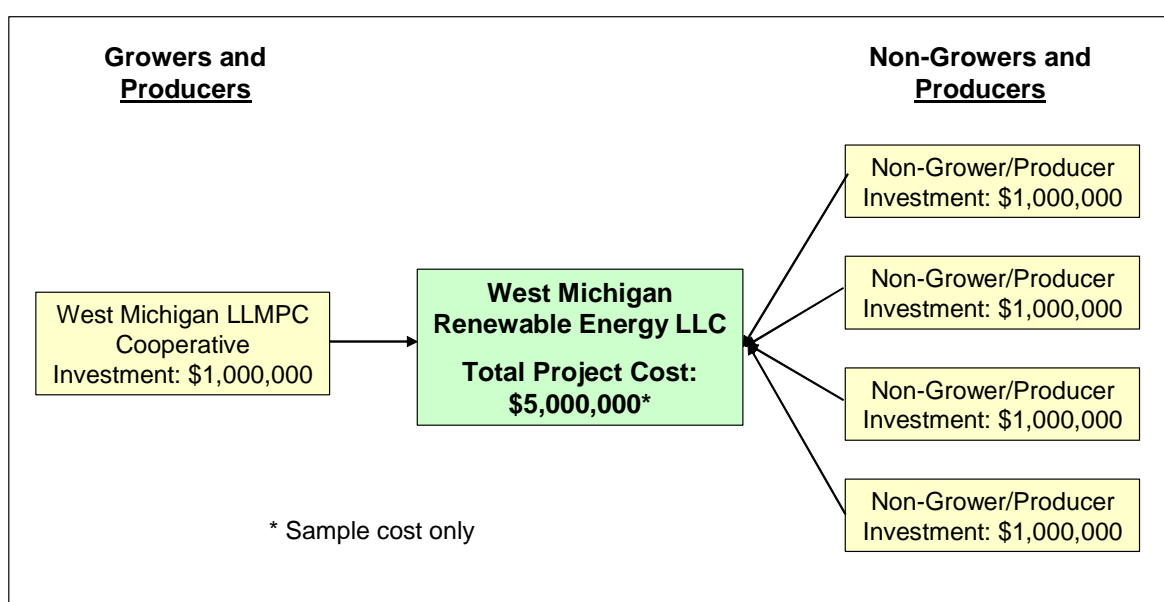
<sup>29</sup> Frame, D., et al (2001). University of Wisconsin UW Extension. Anaerobic Digesters and Methane Production. A3766.

The cooperative would contribute a portion of the investment; all remaining capital would come from individual non-cooperative private investors (see the diagram below).

The amount of capital required for investment in the LLC should be set high enough that the investor must show some commitment to the project (say, \$5,000) but allow those who desire to invest larger amounts; this allows the members to contribute as much as they can afford.

Members of the West Michigan LLMPC Cooperative (i.e. the feedstock suppliers) would be given preferential benefits over non-members. Members may have different tipping fees based on the quality of their manure (e.g., 4% total solids versus 10% total solids).

**Chart 4: Proposed West Michigan Renewable Energy LLC Business Model**



## VIII. Permitting

Moving forward with the project to the commercialization stage will require a lengthy permitting process. The EPA or “authorized states” (through the Clean Water Act) maintains permitting regulations according to the National Pollutant Discharge Elimination System (NPDES). There are five program components of the NPDES. All states vary in their adherence to these programs<sup>30</sup>; Michigan’s status is outlined below:

<b>Table 41: Michigan NPDES Program Status</b>	
Approved State NPDES Permit Program	Yes
Approved to Regulate Federal Facilities	Yes
Approved State Pretreatment Program	Yes
Approved General Permits Program	Yes
Approved Biosolids Program	No

Note: Only seven states have an approved biosolids program; Michigan is not one of them.

Digestate is a biosolid, defined by the Environmental Protection Agency as: “carefully treated and monitored and must be used in accordance with regulatory requirements.” There are two classes of biosolids:

- Class A: no detectible levels of pathogens
- Class B: detectible levels of pathogens<sup>31</sup>

There are crop harvesting restrictions for Class B biosolids. The digestate produced by the four technologies analyzed for this report will be Class A biosolids if swine manure is used. Any biosolid used for land application must abide by the federal biosolids rule 40 CFR Part 503<sup>32</sup>.

The NPDES requires that any facility that discharges material considered to be a pollutant that is derived from a “point source” should obtain a **NPDES Permit**. Anaerobic digesters fall under this requirement. This permitting process requires at least 3 to 6 months.

A **Water Discharge Permit** will be required for the disposal of the wastewater from the anaerobic digester. If the wastewater is discharged into a public water treatment facility (POTW, or Public Owned Treatment Work) a **Pretreatment or Industrial Users Permit** may be required.

A **Construction/Stormwater** permit is required to build the digester, since the ground will be disturbed during construction and there are concerns about runoff. Additionally, a **Stormwater**

<sup>30</sup> EPA. National Pollutant Discharge Elimination System. State Program Status.  
<http://cfpub.epa.gov/npdes/statestats.cfm>

<sup>31</sup> (2006) Biosolids: Frequently Asked Questions. U.S. Environmental Protection Agency. Updated 3/7/2006.

<sup>32</sup> See A Plain English Guide to the EPA Part 503 Biosolids Rule, available at  
<http://www.epa.gov/owm/mtb/biosolids/503pe/index.htm>

**Prevention Plan** will be required during this permit application; this permit requires about 2 months.

A **Land Application of Biosolids Permit** for the application of the solid digestate material may also be needed.

An **Air Permit** is required, since the anaerobic digester will have a stack (vent) that produces biogas.

There may be need of a **Special-Use Permit** from Zeeland Township.

Because of the complexities that may be involved in the permitting process, FBA recommends that the Department of Environmental Quality be contacted to assist in the application process. The permits can be applied for concurrently.

## **IX. Conclusions and Recommendations**

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Given the nature of the feedstock and operating conditions, a complete mix digester was chosen for West Michigan. Complete mix digesters are more expensive than lagoons and plug-flow types of digesters, and require significantly higher expense to operate. The size of the proposed digester is larger than typical on-farm digesters and has higher than typical capital costs.

Digesters produce two products: biogas and digestate. Biogas contains approximately 2/3 methane. The price the LLMPC can obtain for biogas will be a critical factor in its success. The major hurdle will be locating a host for the gas. Biogas is not equivalent to natural gas and must be cleaned or otherwise prepared before used by a host. There will be a burden upon the host to handle and treat the gas and thus the value the host will give the digester will be lower than its actual methane value.

The digestate, depending upon the digester technology utilized, can be separated into a liquid digestate and a solid digestate component. The liquid component, if not treated, will have nutrients but must be delivered back to the field, which negates the benefit of digesting it in the first place: the principal advantage of digestion is to reduce the volume of material handled on-farm. The only option is to treat the digestate to produce a lower volume solid digestate and a treated liquid component that can be safely discharged. In this scenario, the producer has lowered the burden of the high volume of manure produced on farm, while receiving back from the digester the nutrients that are so valued in the form of a humus-like material.

The use of mortality and offal can significantly increase biogas output, but is currently not an approved disposal method in Michigan. There are additional problems associated with mortality and offal if and when the use of such feedstocks is allowed in Michigan. The digestion of mortality can leave fragments in the digestate (such as bones); the value of digestate from mortality and offal can be lowered due to public perceptions; and the use of mortality and offal require longer hydraulic retention times and higher temperatures (thermophilic vs. mesophilic temperatures) to produce a Class A biosolid.

Commercialization of the West Michigan LLMPC will involve:

1. **Formation of the business structure** that allows producer and non-producer participation.
2. **Obtaining swine manure from producers at no cost.** Producers will not accept a scenario where they are required to deliver the manure to the central digester. Vehicles to pickup the swine manure and transport to the central facility must be built into the capital cost requirements.
3. **West Michigan LLMPC should move to secure agreements from interested producers to ensure the availability of swine manure,** especially among the largest swine producers in the region who will form the majority of the feedstock required for the anaerobic digester.
4. **Selection of the best-fit anaerobic digester technology provider.** A technology vendor should be selected who has experience in the construction of anaerobic digesters.
5. **Formation of a management group experienced in the operation of an anaerobic digester.** The management should have knowledge about potential problems that could affect the digester's performance, such as feedstock consistency, temperature, and pH.

6. **Obtaining a host for the biogas.** Broadening the list of potential hosts allows for favorable options. The historical natural gas price for the past five years has been \$5.95; and the last 12 months averaged \$8.28 per mmBTU. Mr. Bob Bishop, of Bishop Energy Services, LLC Midland, Michigan states that the natural gas price for the next 12 months will average \$8.50. The value should be indexed to the price of natural gas, even if a host is found that uses electricity generation value to rate the value of the biogas.

There are funding opportunities to mitigate the cost of an anaerobic digester, both on the State and Federal level. Many digesters have been assisted in part by grants to offset the capital requirements. Some example funding sources are shown below. The reader is also referred to the Agricultural Biogas Casebook, which shows some sample funding structures for existing anaerobic digesters.

#### Federal

- Great Lakes Regional Biomass Energy Program (RBEP).  
Website: [www.cglg.org/biomass/](http://www.cglg.org/biomass/)
- Renewable Energy Systems and Energy Efficiency Program (REEP)  
Website: [www.rurdev.gov](http://www.rurdev.gov)
- Value Added Producer Grant Program (VAPG)
- AgStar
- Environmental Quality Incentives Program (EQIP)

#### State (Michigan)

- Michigan Biomass Energy Program (MBEP). Qualifying bioenergy projects can receive \$5,000 to \$30,000 grant awards for technology development and demonstration. However, only non-profits, government, or educational institutions may apply.
- Department of Commerce
- Office of Environmental Assistance
- Michigan Department of Agriculture

As the capital costs indicated in the Financial Analysis, 4% total solids in swine manure shows no return on investment. If the total solids content of regional manure averaged closer to 5.5%, the biogas output from the digester would be much higher and improve the economics significantly. West Michigan LLMPC should have tests performed on swine manure from the three largest swine producers in the region. Three samples from each producer should be obtained. Tests should include compositional analysis, to include nutrients, moisture, total solids, volatile solids, BOD and COD. The addition of bedding material, such as straw or hay, could be a low cost method of increasing the solids concentration in the swine manure. Sand can inhibit the performance of complete mix digesters and should not be used as bedding.

In addition to manure sampling, West Michigan LLMPC should obtain an analysis of the digestate produced by the digester technology selected. A determination of the nutrient composition of the

digestate, pathogens, and solids are important to weigh the advantage of the particular technology with regard to the marketing potential of the digestate.

FBA believes the major hurdle for the success of the West Michigan LLMPC project is convincing the feedstock suppliers that a centralized anaerobic digester is a viable solution. Local swine producers give manure away to neighboring farms or use it as a valuable but “free” source of fertilizer for their crops. The anaerobic digester financial model works on the assumption that the biosolids are a revenue stream; swine producers will not pay \$35 per ton for their own manure, even if it is returned in a more manageable form.

The original purpose of this report was to find an alternate method of disposal of swine wastes. A centrally-located anaerobic digester for the collection of swine waste will be feasible only if the members of the venture can economically benefit from the digester, or the digester is installed to reduce a nuisance factor, and the disposal of swine manure is mandated.

FBA believes the West Michigan LLMPC will be a profitable venture if:

- Swine producers invest in the digester as a “cost of doing business” to reduce odor complaints and to comply with regulations.
- Project funding in the form of grants and other subsidies lowers the capital investment requirements for the producer investors.
- The total solids content in the manure is increased to an average of 6% to generate sufficient biogas and biosolids to see a 15% total return in investment.

Given the current assumptions used in this report, unless and/or until the cost of manure application on land becomes a financial liability (perceived or real) to the producer the feasibility of a centralized disposal site cannot generate sufficient returns to justify such an investment.

This concludes the West Michigan LLMPC Feasibility Study. If you have any questions relating to this feasibility study report, contact:

Gerald Sherfy  
Frazier, Barnes & Associates, LLC  
1835 Union Avenue, Suite 110  
Memphis, TN 38104  
Phone: (901) 725-7258  
Fax: (901) 725-7245  
Email: fbaGerald@FrazierBarnes.com

## **Addenda**

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1. Glossary
2. Copy of Survey Letter sent to Local Producers
3. Proforma – Waste Energy Solutions – 4% Total Solids
4. Proforma – Waste Energy Solutions – 6% Total Solids
5. Proforma – RCM-Biothane – 4% Total Solids
6. Proforma – RCM-Biothane – 6% Total Solids
7. Proforma – Andigen – 4% Total Solids
8. Proforma – Andigen – 6% Total Solids
9. Proforma – Biopower Technologies – 4% Total Solids
10. Proforma – Biopower Technologies – 4% Total Solids
11. Transporting Manure to a Regional Anaerobic Digester

## **Glossary**

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**Anaerobic.** In the context of this feasibility study, anaerobic refers to a process that operates without the presence of oxygen. Certain microbes, such as those that operate in an anaerobic digester, do so without the need of oxygen.

**Biogas.** A gas produced by anaerobic digestion. Principally methane, carbon dioxide, and trace gases such as hydrogen sulfide. Methane content varies from 50% to 90%.

**BOD.** Biological oxygen demand. The concentration in organic material that can biodegrade, or the volatile solids that can be converted to methane.

**COD.** Chemical oxygen demand. Oxygen required to break down organic material.

**Effluent.** Products coming out of an anaerobic digester.

**Hydraulic Retention Time (HRT).** Time period measured from the introduction of influent wastes to generation of the effluent from the same waste stream.

**Influent.** The feedstock mix going into an anaerobic digester.

**Mesophilic.** Operating in a temperature range of approximately 50° to 105°F. Also known as “mid” temperature.

**Thermophilic.** Operating in a temperature range of 105°F and higher. Also known as “high” temperature.

**Psychrophilic.** Operating in a low temperature range (less than 50°F).

**Volatile Solids.** The amount of material present in the total solids that can potentially biodegrade (be converted to biogas).

**Copy of Survey Letter Sent to Michigan Producers**

MICHIGAN STATE  
UNIVERSITY  
EXTENSION

November 22, 2004

Dear Livestock Producer,

Several months ago the West Michigan Co-Gen project final report was released on the feasibility of burning dry manure to produce electricity in West Michigan. The gist of the report was that while the technology exists to produce electricity from manure fuel, the infrastructure to support moving "green power" onto the power grid did not exist in Michigan. However, with the recent passage of net metering legislation, many of those barriers have been removed. While there is still more work that has to be done before the way is clear for power generated from agricultural by-products to end up on the grid, this is a huge first step.

The co-gen feasibility study mentioned above did not address converting liquid livestock manure into energy because that was outside the scope of the study. However, a feasibility study has been funded to investigate this conversion process. The intent of the feasibility study is to determine the viability of converting large volumes of liquid livestock manure into high quality methane at a centrally located (regional) anaerobic digestion processing plant. If the feasibility study conclusions are positive, the outcome could be the formation of a producer-owned business that would generate high quality methane from liquid manure plus several other value-added products (e.g. hydrogen, compost, dry ice, methanol, etc.).

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**OTTAWA COUNTY****MSU Extension**

333 Clinton Street  
Grand Haven, MI 49417-1329  
Grand Haven (616) 846-8250  
Toll Free: 1-800-764-4111 X 8250  
FAX: (616) 846-0655  
E-mail: [ottawa@msue.msu.edu](mailto:ottawa@msue.msu.edu)  
Web: [www.msue.msu.edu/ottawa](http://www.msue.msu.edu/ottawa)

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*Michigan State University,  
U.S. Department of Agriculture and  
counties cooperating.*

*MSU is an affirmative action,  
equal-opportunity institution.*

It is important to understand that this project focuses on producing high quality methane, not electricity. This is important for two reasons: there is significant cost savings by not having to build a power generating plant and the lack of a "green power" infrastructure in Michigan will not affect producing methane. Some preliminary investigation into the receptivity of businesses in purchasing high quality methane in Southern Ottawa County was positive, especially methane produced from anaerobic digestion, which is considered a "green" technology.

**The purposes of this letter are twofold:**

First, to invite you to participate in this project. Your livestock operation is a potential source of liquid manure. At this time we are only trying to determine your level of interest. A meeting to provide more detailed information about this project and it's implications for you is scheduled for **Thursday, January 6, 2005** from 10:00-12:00 noon at the Zeeland Township Hall (see enclosed meeting brochure for more information).

Second, to determine the volume of liquid manure in Ottawa and Allegan Counties. Enclosed is a one-page six-question survey. Please fill it out and send it back in the self-addressed stamped envelope by **Friday, December 31, 2004**.

Information gathered from this survey will be reported as a composite and used to establish baseline data, including all manure analysis. Questions regarding this study can be

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2

answered by contacting either myself at the address or phone number in the left margin of this letter or Brandon Hill, Nutrient Management Consultant, Hamilton Farm Bureau at 616/836-5162 or [bhill@hfb.com](mailto:bhill@hfb.com).

If you have questions or concerns regarding your rights as a study participant, or are dissatisfied at any time with any aspect of this study, you may contact – anonymously, if you wish – Peter Vasilenko, Ph.D., Chair of the University Committee on Research Involving Human Subjects (UCRIHS) by phone: (517) 355-2180, fax: (517) 432-4503, e-mail: [ucrihs@msu.edu](mailto:ucrihs@msu.edu), or regular mail: 202 Olds Hall, East Lansing, MI 48824.

Please send in your survey by December 31, 2004 and put on your calendar to attend the methane production meeting Thursday, January 6, 2005.

Sincerely,



M. Charles Gould  
ANR-Nutrient Management Educator  
Michigan State University Extension

c.

Frazier, Rod  
Guikema, Dave  
Hill, Brandon  
Krupp, Ira  
Pistis, Chuck  
Robb, Bill  
Wylie, Paul

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## Exhibit 1

## Exhibit 1

# Waste Energy Solutions (100% Swine Manure, 6% TS)

# Exhibit 2

Total Project Cost	\$12,478,363	
Financed Portion	\$6,239,181	50.0%
Equity	\$6,239,181	50.0%

Percent of Capacity Utilized  
Gallons Processed Per Day

Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity
Yr. 1	Yr. 2	Yr. 3	Yr. 4	Yr. 5	Yr. 6	Yr. 7	Yr. 8	Yr. 9	Yr. 10	
75%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
75,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000

FEEDSTOCKS USED	Gallons/Year	Tip Fee											
Swine Manure	100,000	\$0.000	per gallon	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Corn Silage	0	\$0.000	per gallon	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Yellow Grease	0	\$0.000	per gallon	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Mortality	0	\$0.000	per gallon	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Offal	0	\$0.000	per gallon	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Food Processing Waste	0	\$0.000	per gallon	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
(Equivalent)													
eedstock Cost Per Year				\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0

PRODUCTS	Volume	Value											
Methane (mmBTU/year)	65,900	\$3.35	per mmBTU	\$185,573	\$220,764	\$220,764	\$220,764	\$220,764	\$220,764	\$220,764	\$220,764	\$220,764	\$220,764
Electricity (kWh)	0	\$0.00	per kWh										
Liquid Replacement Fertilizer	16,950	\$30.00	per Acre	\$381,375	\$508,500	\$508,500	\$508,500	\$508,500	\$508,500	\$508,500	\$508,500	\$508,500	\$508,500
Solid Bedding/Plant Material	15,750	\$20.00	per Ton	\$236,250	\$315,000	\$315,000	\$315,000	\$315,000	\$315,000	\$315,000	\$315,000	\$315,000	\$315,000
Total Product Value				\$783,198	\$1,044,264	\$1,044,264	\$1,044,264	\$1,044,264	\$1,044,264	\$1,044,264	\$1,044,264	\$1,044,264	\$1,044,264

FINANCIALS													
\$823,500	Product Value Per Gallon	\$0.0298	\$0.0298	\$0.0298	\$0.0298	\$0.0298	\$0.0298	\$0.0298	\$0.0298	\$0.0298	\$0.0298	\$0.0298	\$0.0298
\$823,500	Feedstock Cost Per Gallon	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000
	Gross Margin (Annual)	\$783,198	\$1,044,264	\$1,044,264	\$1,044,264	\$1,044,264	\$1,044,264	\$1,044,264	\$1,044,264	\$1,044,264	\$1,044,264	\$1,044,264	\$1,044,264
	Gross Margin Per Gallon	\$0.030	\$0.030	\$0.030	\$0.030	\$0.030	\$0.030	\$0.030	\$0.030	\$0.030	\$0.030	\$0.030	\$0.030

## Processing Costs

FIXED COSTS	Cost/Gal.												
Insurance & Taxes	\$0.0018	\$64,027	\$64,027	\$64,027	\$64,027	\$64,027	\$64,027	\$64,027	\$64,027	\$64,027	\$64,027	\$64,027	\$64,027
Labor & Benefits	\$0.0010	\$35,000	\$35,000	\$35,000	\$35,000	\$35,000	\$35,000	\$35,000	\$35,000	\$35,000	\$35,000	\$35,000	\$35,000
Operation	\$0.0000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Maintenance	\$0.0002	\$5,250	\$7,140	\$7,283	\$7,428	\$7,577	\$7,729	\$7,883	\$8,041	\$8,202	\$8,366	\$8,530	\$8,694
VARIABLE COSTS													
Supplies	\$0.0000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Electricity	\$0.0036	\$94,500	\$128,520	\$131,090	\$133,712	\$136,386	\$139,114	\$141,896	\$144,734	\$147,629	\$150,582	\$153,535	\$156,488
Chemicals	\$0.0001	\$2,625	\$3,570	\$3,641	\$3,714	\$3,789	\$3,864	\$3,942	\$4,020	\$4,101	\$4,183	\$4,265	\$4,347
Trucking Expense	\$0.0005	\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$21,324	\$21,734
Other Miscellaneous Expenses	\$0.0005	\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$21,324	\$21,734
Total w/out SG&A	\$0.0049	\$128,625	\$174,930	\$178,429	\$181,997	\$185,637	\$189,350	\$193,137	\$197,000	\$200,940	\$204,958	\$209,032	\$213,164
SG&A	\$0.0004	\$9,844	\$13,388	\$13,655	\$13,928	\$14,207	\$14,491	\$14,781	\$15,076	\$15,378	\$15,686	\$15,991	\$16,296
Total Operating & SG&A	\$0.0053	\$138,469	\$188,318	\$192,084	\$195,926	\$199,844	\$203,841	\$207,918	\$212,076	\$216,318	\$220,644	\$225,043	\$229,460
Depreciation Expense	\$0.0245	\$856,895	\$856,895	\$856,895	\$856,895	\$856,895	\$856,895	\$856,895	\$856,895	\$856,895	\$856,895	\$856,895	\$856,895
Interest Expense	\$0.0146	\$511,813	\$476,296	\$438,155	\$398,962	\$352,473	\$304,426	\$252,534	\$196,492	\$135,966	\$70,598	\$0	\$0
Subtotal Depreciation & Interest	\$0.0391	\$1,368,507	\$1,333,191	\$1,295,049	\$1,253,856	\$1,209,368	\$1,161,320	\$1,109,429	\$1,053,386	\$992,860	\$927,492	\$856,895	\$783,198
Total Processing Cost	\$0.0444	\$1,506,976	\$1,521,509	\$1,487,133	\$1,449,782	\$1,409,212	\$1,365,161	\$1,317,347	\$1,265,462	\$1,209,178	\$1,148,136	\$1,086,895	\$1,025,654
Federal Credits		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Net Operating Income Before Taxes (EBIT)		\$-723,779	\$-477,245	\$-442,870	\$-405,518	\$-364,948	\$-320,898	\$-273,083	\$-221,199	\$-164,914	\$-103,873	\$-42,870	\$18,182
Return on Equity Investment	10 yr Avg:	-11.60%	-7.65%	-7.10%	-6.50%	-5.85%	-5.14%	-4.38%	-3.55%	-2.64%	-1.66%	-0.68%	0.34%

# RCM-Biothane (100% Swine Manure, 4% TS)

## Exhibit 3

Total Project Cost	\$6,353,750	
Financed Portion	\$3,176,875	50.0%
Equity	\$3,176,875	50.0%

Percent of Capacity Utilized  
Gallons Processed Per Day

Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity
Yr. 1	Yr. 2	Yr. 3	Yr. 4	Yr. 5	Yr. 6	Yr. 7	Yr. 8	Yr. 9	Yr. 10	Yr. 10	Yr. 10
75%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
75,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000

FEEDSTOCKS USED	Units/Year	Tip Fee											
Swine Manure	35,000,000 gallons	\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Corn Silage	0	\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Yellow Grease	0	\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Mortality	0	\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Offal	0 tons	\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Food Processing Waste	0	\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
(Equivalent) feedstock Cost Per Year			\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0

PRODUCTS	Volume	Value											
Methane (mmBTU/year)	40,850	\$3.35 per mmBTU	\$102,635	\$136,846	\$136,846	\$136,846	\$136,846	\$136,846	\$136,846	\$136,846	\$136,846	\$136,846	\$136,846
Electricity (kWh)	0	\$0.00 per kWh											
Digestate (tons/year)	13,500	\$35.00 per Ton	\$354,375	\$472,500	\$472,500	\$472,500	\$472,500	\$472,500	\$472,500	\$472,500	\$472,500	\$472,500	\$472,500
Total Product Value			\$457,010	\$609,346	\$609,346	\$609,346	\$609,346	\$609,346	\$609,346	\$609,346	\$609,346	\$609,346	\$609,346

FINANCIALS													
Product Value Per Gallon	\$0.0174	\$0.0174	\$0.0174	\$0.0174	\$0.0174	\$0.0174	\$0.0174	\$0.0174	\$0.0174	\$0.0174	\$0.0174	\$0.0174	\$0.0174
Feedstock Cost Per Gallon	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000
Gross Margin (Annual)	\$457,010	\$609,346	\$609,346	\$609,346	\$609,346	\$609,346	\$609,346	\$609,346	\$609,346	\$609,346	\$609,346	\$609,346	\$609,346
Gross Margin Per Gallon	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017

### Processing Costs

FIXED COSTS	Cost/Gal.												
Insurance & Taxes	\$0.0029	\$99,750	\$99,750	\$99,750	\$99,750	\$99,750	\$99,750	\$99,750	\$99,750	\$99,750	\$99,750	\$99,750	\$99,750
Labor & Benefits	\$0.0038	\$132,300	\$132,300	\$132,300	\$132,300	\$132,300	\$132,300	\$132,300	\$132,300	\$132,300	\$132,300	\$132,300	\$132,300
Operation	\$0.0000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Maintenance	\$0.0007	\$18,375	\$24,990	\$25,490	\$26,000	\$26,520	\$27,050	\$27,591	\$28,143	\$28,706	\$29,280	\$29,863	\$30,446
VARIABLE COSTS													
Supplies	\$0.0000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Electricity	\$0.0007	\$18,375	\$24,990	\$25,490	\$26,000	\$26,520	\$27,050	\$27,591	\$28,143	\$28,706	\$29,280	\$29,863	\$30,446
Chemicals	\$0.0004	\$10,500	\$14,280	\$14,566	\$14,857	\$15,154	\$15,457	\$15,766	\$16,082	\$16,403	\$16,731	\$17,063	\$17,400
Trucking Expense	\$0.0005	\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$21,331	\$21,754
Other Miscellaneous Expenses	\$0.0005	\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$21,331	\$21,754
Total w/out SG&A	\$0.0028	\$305,550	\$332,010	\$334,009	\$336,048	\$338,128	\$340,250	\$342,414	\$344,621	\$346,873	\$349,169	\$351,506	\$353,887
SG&A	\$0.0005	\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$21,331	\$21,754
Total Operating & SG&A	\$0.0033	\$318,675	\$349,860	\$352,216	\$354,620	\$357,071	\$359,571	\$362,122	\$364,723	\$367,377	\$370,083	\$372,837	\$375,641
Depreciation Expense	\$0.0125	\$436,625	\$436,625	\$436,625	\$436,625	\$436,625	\$436,625	\$436,625	\$436,625	\$436,625	\$436,625	\$436,625	\$436,625
Interest Expense	\$0.0074	\$260,504	\$242,521	\$223,100	\$202,126	\$179,473	\$155,008	\$128,586	\$100,050	\$69,231	\$35,947	\$0	\$0
Subtotal Depreciation & Interest	\$0.0199	\$697,129	\$679,146	\$659,725	\$638,751	\$616,098	\$591,633	\$565,211	\$536,675	\$505,856	\$472,572	\$436,625	\$400,000
Total Processing Cost	\$0.0232	\$1,015,804	\$1,029,006	\$1,011,941	\$993,370	\$973,169	\$951,204	\$927,333	\$901,398	\$873,233	\$842,655	\$810,000	\$776,000
Federal Credits		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Net Operating Income Before Taxes (EBIT)		\$-558,794	\$-419,660	\$-402,595	\$-384,024	\$-363,823	\$-341,858	\$-317,987	\$-292,052	\$-263,887	\$-233,309	\$-200,000	\$-165,000
Return on Equity Investment	10 yr Avg:	-11.3%	-17.59%	-13.21%	-12.67%	-12.09%	-11.45%	-10.76%	-10.01%	-9.19%	-8.31%	-7.34%	-6.34%

# RCM-Biothane (100% Swine Manure, 6% TS)

## Exhibit 4

Total Project Cost	\$6,353,750	
Financed Portion	\$3,176,875	50.0%
Equity	\$3,176,875	50.0%

Percent of Capacity Utilized  
Gallons Processed Per Day

Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity
Yr. 1	Yr. 2	Yr. 3	Yr. 4	Yr. 5	Yr. 6	Yr. 7	Yr. 8	Yr. 9	Yr. 10	Yr. 10
75%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
75,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000

FEEDSTOCKS USED	Units/Year	Tip Fee											
Swine Manure	35,000,000 gallons	\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Corn Silage	0	\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Yellow Grease	0	\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Mortality	0	\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Offal	0 tons	\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Food Processing Waste	0	\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
(Equivalent) Feedstock Cost Per Year			\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0

PRODUCTS	Volume	Value											
Methane (mmBTU/year)	61,274	\$3.35 per mmBTU	\$153,952	\$205,269	\$205,269	\$205,269	\$205,269	\$205,269	\$205,269	\$205,269	\$205,269	\$205,269	\$205,269
Electricity (kWh)	0	\$0.00 per kWh											
Digestate (tons/year)	20,250	\$35.00 per Ton	\$531,563	\$708,750	\$708,750	\$708,750	\$708,750	\$708,750	\$708,750	\$708,750	\$708,750	\$708,750	\$708,750
Total Product Value			\$685,514	\$914,019	\$914,019	\$914,019	\$914,019	\$914,019	\$914,019	\$914,019	\$914,019	\$914,019	\$914,019

## FINANCIALS

Product Value Per Gallon	\$0.0261	\$0.0261	\$0.0261	\$0.0261	\$0.0261	\$0.0261	\$0.0261	\$0.0261	\$0.0261	\$0.0261	\$0.0261	\$0.0261	\$0.0261
Feedstock Cost Per Gallon	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000
Gross Margin (Annual)	\$685,514	\$914,019	\$914,019	\$914,019	\$914,019	\$914,019	\$914,019	\$914,019	\$914,019	\$914,019	\$914,019	\$914,019	\$914,019
Gross Margin Per Gallon	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026

## Processing Costs

FIXED COSTS	Cost/Gal.												
Insurance & Taxes	\$0.0029	\$99,750	\$99,750	\$99,750	\$99,750	\$99,750	\$99,750	\$99,750	\$99,750	\$99,750	\$99,750	\$99,750	\$99,750
Labor & Benefits	\$0.0038	\$132,300	\$132,300	\$132,300	\$132,300	\$132,300	\$132,300	\$132,300	\$132,300	\$132,300	\$132,300	\$132,300	\$132,300
Operation	\$0.0000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Maintenance	\$0.0007	\$18,375	\$24,990	\$25,490	\$26,000	\$26,520	\$27,050	\$27,591	\$28,143	\$28,706	\$29,280	\$29,860	\$30,445
VARIABLE COSTS													
Supplies	\$0.0000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Electricity	\$0.0007	\$18,375	\$24,990	\$25,490	\$26,000	\$26,520	\$27,050	\$27,591	\$28,143	\$28,706	\$29,280	\$29,860	\$30,445
Chemicals	\$0.0004	\$10,500	\$14,280	\$14,566	\$14,857	\$15,154	\$15,457	\$15,766	\$16,082	\$16,403	\$16,731	\$17,064	\$17,401
Trucking Expense	\$0.0005	\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$21,331	\$21,754
Other Miscellaneous Expenses	\$0.0005	\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$21,331	\$21,754
Total w/out SG&A	\$0.0028	\$305,550	\$332,010	\$334,009	\$336,048	\$338,128	\$340,250	\$342,414	\$344,621	\$346,873	\$349,169	\$351,506	\$353,887
SG&A	\$0.0005	\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$21,331	\$21,754
Total Operating & SG&A	\$0.0033	\$318,675	\$349,860	\$352,216	\$354,620	\$357,071	\$359,571	\$362,122	\$364,723	\$367,377	\$370,083	\$372,837	\$375,641
Depreciation Expense	\$0.0125	\$436,625	\$436,625	\$436,625	\$436,625	\$436,625	\$436,625	\$436,625	\$436,625	\$436,625	\$436,625	\$436,625	\$436,625
Interest Expense	\$0.0074	\$260,504	\$242,521	\$223,100	\$202,126	\$179,473	\$155,008	\$128,586	\$100,050	\$69,231	\$35,947	\$0	\$0
Subtotal Depreciation & Interest	\$0.0199	\$697,129	\$679,146	\$659,725	\$638,751	\$616,098	\$591,633	\$565,211	\$536,675	\$505,856	\$472,572	\$436,625	\$400,625
Total Processing Cost	\$0.0232	\$1,015,804	\$1,029,006	\$1,011,941	\$993,370	\$973,169	\$951,204	\$927,333	\$901,398	\$873,233	\$842,655	\$810,460	\$777,655
Federal Credits		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Net Operating Income Before Taxes (EBIT)		-\$330,289	-\$114,987	-\$97,922	-\$79,351	-\$59,150	-\$37,185	-\$13,313	\$12,621	\$40,786	\$71,364	\$102,549	\$133,739
Return on Equity Investment	10 yr Avg:	-1.9%	-10.40%	-3.62%	-3.08%	-2.50%	-1.86%	-1.17%	-0.42%	0.40%	1.28%	2.25%	3.25%

# Andigen (100% Swine Manure, 4% TS)

## Exhibit 5

Total Project Cost	\$4,581,232	
Financed Portion	\$2,290,616	50.0%
Equity	\$2,290,616	50.0%

Percent of Capacity Utilized  
Gallons Processed Per Day

Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity
Yr. 1	Yr. 2	Yr. 3	Yr. 4	Yr. 5	Yr. 6	Yr. 7	Yr. 8	Yr. 9	Yr. 10	Yr. 10
75%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
75,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000

FEEDSTOCKS USED	Units/Year	Tip Fee											
Swine Manure	35,000,000 gallons	\$0.000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Corn Silage	0	\$0.000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Yellow Grease	0	\$0.000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Mortality	0	\$0.000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Offal	0 tons	\$0.000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Food Processing Waste	0	\$0.000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
(Equivalent) feedstock Cost Per Year				\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0

PRODUCTS	Volume	Value											
Methane (mmBTU/year)	36,681	\$3.35	per mmBTU	\$92,160	\$122,880	\$122,880	\$122,880	\$122,880	\$122,880	\$122,880	\$122,880	\$122,880	\$122,880
Electricity (kWh)	0	\$0.00	per kWh										
Digestate (tons/year)	13,500	\$35.00	per Ton	\$354,375	\$472,500	\$472,500	\$472,500	\$472,500	\$472,500	\$472,500	\$472,500	\$472,500	\$472,500
Total Product Value				\$446,535	\$595,380	\$595,380	\$595,380	\$595,380	\$595,380	\$595,380	\$595,380	\$595,380	\$595,380

FINANCIALS													
Product Value Per Gallon		\$0.0170	\$0.0170	\$0.0170	\$0.0170	\$0.0170	\$0.0170	\$0.0170	\$0.0170	\$0.0170	\$0.0170	\$0.0170	\$0.0170
Feedstock Cost Per Gallon		\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000
Gross Margin (Annual)		\$446,535	\$595,380	\$595,380	\$595,380	\$595,380	\$595,380	\$595,380	\$595,380	\$595,380	\$595,380	\$595,380	\$595,380
Gross Margin Per Gallon		\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017

### Processing Costs

FIXED COSTS	Cost/Gal.												
Insurance & Taxes	\$0.0020		\$70,000	\$70,000	\$70,000	\$70,000	\$70,000	\$70,000	\$70,000	\$70,000	\$70,000	\$70,000	\$70,000
Labor & Benefits	\$0.0027		\$94,500	\$96,390	\$98,318	\$100,284	\$102,290	\$104,336	\$106,422	\$108,551	\$110,722	\$112,936	\$112,936
Operation	\$0.0000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Maintenance	\$0.0003		\$7,875	\$10,710	\$10,924	\$11,143	\$11,366	\$11,593	\$11,825	\$12,061	\$12,302	\$12,548	\$12,548
VARIABLE COSTS													
Supplies	\$0.0001		\$2,825	\$3,570	\$3,841	\$3,714	\$3,789	\$3,864	\$3,942	\$4,020	\$4,101	\$4,183	\$4,183
Electricity	\$0.0007		\$18,375	\$24,990	\$25,490	\$26,000	\$26,520	\$27,050	\$27,591	\$28,143	\$28,706	\$29,280	\$29,280
Chemicals	\$0.0004		\$10,500	\$14,280	\$14,566	\$14,857	\$15,154	\$15,457	\$15,766	\$16,082	\$16,403	\$16,731	\$16,731
Trucking Expense	\$0.0005		\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$20,914
Other Miscellaneous Expenses	\$0.0005		\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$20,914
Total w/out SG&A	\$0.0025		\$230,125	\$255,640	\$259,353	\$263,140	\$267,003	\$270,943	\$274,962	\$279,061	\$283,242	\$287,507	\$287,507
SG&A	\$0.0004		\$9,844	\$13,388	\$13,855	\$13,928	\$14,207	\$14,491	\$14,781	\$15,076	\$15,378	\$15,686	\$15,686
Total Operating & SG&A	\$0.0029		\$239,969	\$269,028	\$273,008	\$277,068	\$281,210	\$285,434	\$289,742	\$294,137	\$298,620	\$303,192	\$303,192
Depreciation Expense	\$0.0090		\$313,969	\$313,969	\$313,969	\$313,969	\$313,969	\$313,969	\$313,969	\$313,969	\$313,969	\$313,969	\$313,969
Interest Expense	\$0.0054		\$187,831	\$174,865	\$160,862	\$145,738	\$129,405	\$111,765	\$92,714	\$72,139	\$49,918	\$25,919	\$25,919
Subtotal Depreciation & Interest	\$0.0143		\$501,800	\$488,834	\$474,831	\$459,707	\$443,374	\$425,734	\$406,683	\$386,108	\$363,887	\$339,888	\$339,888
Total Processing Cost	\$0.0172		\$741,768	\$757,861	\$747,839	\$736,776	\$724,584	\$711,168	\$696,426	\$680,245	\$662,507	\$643,080	\$643,080
Federal Credits			\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Net Operating Income Before Taxes (EBIT)			-\$295,233	-\$162,481	-\$152,459	-\$141,395	-\$129,203	-\$115,788	-\$101,045	-\$84,865	-\$67,127	-\$47,700	-\$47,700
Return on Equity Investment	10 yr Avg:	-5.7%	-12.89%	-7.09%	-6.66%	-6.17%	-5.64%	-5.05%	-4.41%	-3.70%	-2.93%	-2.08%	-2.08%

**Andigen (100% Swine Manure, 6% TS)**

**Exhibit 6**

Total Project Cost	\$4,581,232	
Financed Portion	\$2,290,616	50.0%
Equity	\$2,290,616	50.0%

**Percent of Capacity Utilized  
Gallons Processed Per Day**

Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity
Yr. 1	Yr. 2	Yr. 3	Yr. 4	Yr. 5	Yr. 6	Yr. 7	Yr. 8	Yr. 9	Yr. 10	
75%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
75,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000

FEEDSTOCKS USED		Units/Year	Tip Fee										
Swine Manure	35,000,000	gallons	\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Corn Silage	0		\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Yellow Grease	0		\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Mortality	0		\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Offal	0	tons	\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Food Processing Waste	0		\$0.000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
(Equivalent)	Feedstock Cost Per Year			\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0

PRODUCTS		Volume	Value										
Methane (mmBTU/year)	55,021	\$3.35	per mmBTU	\$138,240	\$184,320	\$184,320	\$184,320	\$184,320	\$184,320	\$184,320	\$184,320	\$184,320	\$184,320
Electricity (kWh)	0	\$0.00	per kWh										
Digestate (tons/year)	20,250	\$35.00	per Ton	\$531,563	\$708,750	\$708,750	\$708,750	\$708,750	\$708,750	\$708,750	\$708,750	\$708,750	\$708,750
Total Product Value				\$669,803	\$893,070	\$893,070	\$893,070	\$893,070	\$893,070	\$893,070	\$893,070	\$893,070	\$893,070

FINANCIALS													
Product Value Per Gallon		\$0.0255	\$0.0255	\$0.0255	\$0.0255	\$0.0255	\$0.0255	\$0.0255	\$0.0255	\$0.0255	\$0.0255	\$0.0255	\$0.0255
Feedstock Cost Per Gallon		\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000
Gross Margin (Annual)		\$669,803	\$893,070	\$893,070	\$893,070	\$893,070	\$893,070	\$893,070	\$893,070	\$893,070	\$893,070	\$893,070	\$893,070
Gross Margin Per Gallon		\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026

**Processing Costs**

FIXED COSTS		Cost/Gal.											
Insurance & Taxes		\$0.0020	\$70,000	\$70,000	\$70,000	\$70,000	\$70,000	\$70,000	\$70,000	\$70,000	\$70,000	\$70,000	\$70,000
Labor & Benefits		\$0.0027	\$94,500	\$96,390	\$98,318	\$100,284	\$102,290	\$104,336	\$106,422	\$108,551	\$110,722	\$112,936	\$115,190
Operation		\$0.0000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Maintenance		\$0.0003	\$7,875	\$10,710	\$10,924	\$11,143	\$11,366	\$11,593	\$11,825	\$12,061	\$12,302	\$12,548	\$12,797
VARIABLE COSTS													
Supplies		\$0.0001	\$2,625	\$3,570	\$3,641	\$3,714	\$3,789	\$3,864	\$3,942	\$4,020	\$4,101	\$4,183	\$4,266
Electricity		\$0.0007	\$18,375	\$24,990	\$25,490	\$26,000	\$26,520	\$27,050	\$27,591	\$28,143	\$28,706	\$29,280	\$29,864
Chemicals		\$0.0004	\$10,500	\$14,280	\$14,566	\$14,857	\$15,154	\$15,457	\$15,766	\$16,082	\$16,403	\$16,731	\$17,064
Trucking Expense		\$0.0005	\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$21,331
Other Miscellaneous Expenses		\$0.0005	\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$21,331
Total w/out SG&A		\$0.0025	\$230,125	\$255,640	\$259,353	\$263,140	\$267,003	\$270,943	\$274,962	\$279,061	\$283,242	\$287,507	\$291,856
SG&A		\$0.0004	\$9,844	\$13,388	\$13,655	\$13,928	\$14,207	\$14,491	\$14,781	\$15,076	\$15,378	\$15,686	\$15,999
Total Operating & SG&A		\$0.0029	\$239,969	\$269,028	\$273,008	\$277,068	\$281,210	\$285,434	\$289,742	\$294,137	\$298,620	\$303,192	\$307,855
Depreciation Expense		\$0.0090	\$313,969	\$313,969	\$313,969	\$313,969	\$313,969	\$313,969	\$313,969	\$313,969	\$313,969	\$313,969	\$313,969
Interest Expense		\$0.0054	\$187,831	\$174,865	\$160,862	\$145,738	\$129,405	\$111,765	\$92,714	\$72,139	\$49,918	\$25,919	\$0
Subtotal Depreciation & Interest		\$0.0143	\$501,800	\$488,834	\$474,831	\$459,707	\$443,374	\$425,734	\$406,683	\$386,108	\$363,887	\$339,888	\$315,888
Total Processing Cost		\$0.0172	\$741,768	\$757,861	\$747,839	\$736,776	\$724,584	\$711,168	\$696,426	\$680,245	\$662,507	\$643,080	\$623,743
Federal Credits			\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Net Operating Income Before Taxes (EBIT)			\$-71,966	\$135,209	\$145,232	\$156,295	\$168,487	\$181,902	\$196,645	\$212,825	\$230,563	\$249,990	\$271,113
Return on Equity Investment	10 yr Avg:	7.0%	-3.14%	5.90%	6.34%	6.82%	7.36%	7.94%	8.58%	9.29%	10.07%	10.91%	11.81%

# Biopower Technologies (100% Swine Manure, 4% TS)

## Exhibit 7

Total Project Cost	\$3,744,259	
Financed Portion	\$1,872,129	50.0%
Equity	\$1,872,129	50.0%

Percent of Capacity Utilized  
Gallons Processed Per Day

Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity
Yr. 1	Yr. 2	Yr. 3	Yr. 4	Yr. 5	Yr. 6	Yr. 7	Yr. 8	Yr. 9	Yr. 10	
75%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
75,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000

FEEDSTOCKS USED	Units/Year	Tip Fee											
Swine Manure	35,000,000 gallons	\$0.000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Corn Silage	0	\$0.010		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Yellow Grease	0	\$0.000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Mortality	0	\$0.000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Offal	0 tons	\$0.000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Food Processing Waste	0	\$0.000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
(Equivalent) Feedstock Cost Per Year				\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0

PRODUCTS	Volume	Value											
Methane (mmBTU/year)	32,798	\$3.35	per mmBTU	\$82,405	\$109,873	\$109,873	\$109,873	\$109,873	\$109,873	\$109,873	\$109,873	\$109,873	\$109,873
Electricity (kWh)	0	\$0.00	per kWh										
Digestate (tons/year)	13,500	\$35.00	per Ton	\$354,375	\$472,500	\$472,500	\$472,500	\$472,500	\$472,500	\$472,500	\$472,500	\$472,500	\$472,500
Total Product Value				\$436,780	\$582,373	\$582,373	\$582,373	\$582,373	\$582,373	\$582,373	\$582,373	\$582,373	\$582,373

FINANCIALS													
Product Value Per Gallon	\$0.0166	\$0.0166	\$0.0166	\$0.0166	\$0.0166	\$0.0166	\$0.0166	\$0.0166	\$0.0166	\$0.0166	\$0.0166	\$0.0166	\$0.0166
Feedstock Cost Per Gallon	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000
Gross Margin (Annual)	\$436,780	\$582,373	\$582,373	\$582,373	\$582,373	\$582,373	\$582,373	\$582,373	\$582,373	\$582,373	\$582,373	\$582,373	\$582,373
Gross Margin Per Gallon	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017	\$0.017

### Processing Costs

FIXED COSTS	Cost/Gal.												
Insurance & Taxes	\$0.0016		\$54,425	\$54,425	\$54,425	\$54,425	\$54,425	\$54,425	\$54,425	\$54,425	\$54,425	\$54,425	\$54,425
Labor & Benefits	\$0.0021		\$73,500	\$74,970	\$76,469	\$77,999	\$79,559	\$81,150	\$82,773	\$84,428	\$86,117	\$87,839	\$89,599
Operation	\$0.0000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Maintenance	\$0.0007		\$18,375	\$24,990	\$25,490	\$26,000	\$26,520	\$27,050	\$27,591	\$28,143	\$28,706	\$29,280	\$29,864
VARIABLE COSTS													
Supplies	\$0.0000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Electricity	\$0.0003		\$7,875	\$10,710	\$10,924	\$11,143	\$11,366	\$11,593	\$11,825	\$12,061	\$12,302	\$12,548	\$12,798
Chemicals	\$0.0004		\$10,500	\$14,280	\$14,566	\$14,857	\$15,154	\$15,457	\$15,766	\$16,082	\$16,403	\$16,731	\$17,064
Trucking Expense	\$0.0005		\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$21,331
Other Miscellaneous Expenses	\$0.0005		\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$21,331
Total w/out SG&A	\$0.0024		\$190,925	\$215,075	\$218,288	\$221,565	\$224,908	\$228,318	\$231,796	\$235,343	\$238,961	\$242,652	\$246,417
SG&A	\$0.0005		\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$21,331
Total Operating & SG&A	\$0.0029		\$204,050	\$232,925	\$236,495	\$240,136	\$243,851	\$247,639	\$251,503	\$255,445	\$259,465	\$263,566	\$267,748
Depreciation Expense	\$0.0072		\$250,566	\$250,566	\$250,566	\$250,566	\$250,566	\$250,566	\$250,566	\$250,566	\$250,566	\$250,566	\$250,566
Interest Expense	\$0.0044		\$153,515	\$142,918	\$131,473	\$119,112	\$105,783	\$91,346	\$75,776	\$58,959	\$40,798	\$21,184	\$0
Subtotal Depreciation & Interest	\$0.0115		\$404,081	\$393,484	\$382,039	\$369,679	\$356,329	\$341,912	\$326,342	\$309,526	\$291,364	\$271,750	\$250,750
Total Processing Cost	\$0.0144		\$608,131	\$626,409	\$618,534	\$609,815	\$600,180	\$589,551	\$577,845	\$564,971	\$550,830	\$535,316	\$518,498
Federal Credits			\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Net Operating Income Before Taxes (EBIT)			\$-171,351	\$-44,036	\$-36,161	\$-27,442	\$-17,807	\$-7,179	\$4,528	\$17,402	\$31,543	\$47,057	\$64,172
Return on Equity Investment	10 yr Avg:	-1.1%	-9.15%	-2.35%	-1.93%	-1.47%	-0.95%	-0.38%	0.24%	0.93%	1.68%	2.51%	3.41%

# Biopower Technologies (100% Swine Manure, 6% TS)

# Exhibit 8

Total Project Cost	\$3,744,259
Financed Portion	\$1,872,129
Equity	\$1,872,129

50.0%

50.0%

Percent of Capacity Utilized  
Gallons Processed Per Day

Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity
Yr. 1	Yr. 2	Yr. 3	Yr. 4	Yr. 5	Yr. 6	Yr. 7	Yr. 8	Yr. 9	Yr. 10	Yr. 10
75%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
75,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000

FEEDSTOCKS USED	Units/Year	Tip Fee											
Swine Manure	35,000,000 gallons	\$0.000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Corn Silage	0	\$0.010		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Yellow Grease	0	\$0.000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Mortality	0	\$0.000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Offal	0 tons	\$0.000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Food Processing Waste	0	\$0.000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
(Equivalent) Feedstock Cost Per Year				\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0

PRODUCTS	Volume	Value											
Methane (mmBTU/year)	32,798	\$3.35	per mmBTU	\$82,405	\$109,873	\$109,873	\$109,873	\$109,873	\$109,873	\$109,873	\$109,873	\$109,873	\$109,873
Electricity (kWh)	0	\$0.00	per kWh										
Digestate (tons/year)	22,500	\$35.00	per Ton	\$590,625	\$787,500	\$787,500	\$787,500	\$787,500	\$787,500	\$787,500	\$787,500	\$787,500	\$787,500
Total Product Value				\$673,030	\$897,373	\$897,373	\$897,373	\$897,373	\$897,373	\$897,373	\$897,373	\$897,373	\$897,373

FINANCIALS													
Product Value Per Gallon		\$0.0256	\$0.0256	\$0.0256	\$0.0256	\$0.0256	\$0.0256	\$0.0256	\$0.0256	\$0.0256	\$0.0256	\$0.0256	\$0.0256
Feedstock Cost Per Gallon		\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000	\$0.0000
Gross Margin (Annual)		\$673,030	\$897,373	\$897,373	\$897,373	\$897,373	\$897,373	\$897,373	\$897,373	\$897,373	\$897,373	\$897,373	\$897,373
Gross Margin Per Gallon		\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026	\$0.026

## Processing Costs

FIXED COSTS	Cost/Gal.												
Insurance & Taxes	\$0.0016		\$54,425	\$54,425	\$54,425	\$54,425	\$54,425	\$54,425	\$54,425	\$54,425	\$54,425	\$54,425	\$54,425
Labor & Benefits	\$0.0021		\$73,500	\$74,970	\$76,469	\$77,999	\$79,559	\$81,150	\$82,773	\$84,428	\$86,117	\$87,839	\$89,589
Operation	\$0.0000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Maintenance	\$0.0007		\$18,375	\$24,990	\$25,490	\$26,000	\$26,520	\$27,050	\$27,591	\$28,143	\$28,706	\$29,280	\$29,864
VARIABLE COSTS													
Supplies	\$0.0000		\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Electricity	\$0.0003		\$7,875	\$10,710	\$10,924	\$11,143	\$11,366	\$11,593	\$11,825	\$12,061	\$12,302	\$12,548	\$12,798
Chemicals	\$0.0004		\$10,500	\$14,280	\$14,566	\$14,857	\$15,154	\$15,457	\$15,766	\$16,082	\$16,403	\$16,731	\$17,064
Trucking Expense	\$0.0005		\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$21,331
Other Miscellaneous Expenses	\$0.0005		\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$21,331
Total w/out SG&A	\$0.0024		\$190,925	\$215,075	\$218,288	\$221,565	\$224,908	\$228,318	\$231,796	\$235,343	\$238,961	\$242,652	\$246,418
SG&A	\$0.0005		\$13,125	\$17,850	\$18,207	\$18,571	\$18,943	\$19,321	\$19,708	\$20,102	\$20,504	\$20,914	\$21,331
Total Operating & SG&A	\$0.0029		\$204,050	\$232,925	\$236,495	\$240,136	\$243,851	\$247,639	\$251,503	\$255,445	\$259,465	\$263,566	\$267,749
Depreciation Expense	\$0.0072		\$250,566	\$250,566	\$250,566	\$250,566	\$250,566	\$250,566	\$250,566	\$250,566	\$250,566	\$250,566	\$250,566
Interest Expense	\$0.0044		\$153,515	\$142,918	\$131,473	\$119,112	\$105,763	\$91,346	\$75,776	\$58,959	\$40,798	\$21,184	\$0
Subtotal Depreciation & Interest	\$0.0115		\$404,081	\$393,484	\$382,039	\$369,679	\$356,329	\$341,912	\$326,342	\$309,526	\$291,364	\$271,750	\$250,750
Total Processing Cost	\$0.0144		\$608,131	\$626,409	\$618,534	\$609,815	\$600,180	\$589,551	\$577,845	\$564,971	\$550,830	\$535,316	\$518,500
Federal Credits			\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Net Operating Income Before Taxes (EBIT)			\$64,899	\$270,964	\$278,839	\$287,558	\$297,193	\$307,821	\$319,528	\$332,402	\$346,543	\$362,057	\$378,918
Return on Equity Investment	10 yr Avg:	15.3%	3.47%	14.47%	14.89%	15.36%	15.87%	16.44%	17.07%	17.76%	18.51%	19.34%	20.23%

## Exhibit 9: Transporting Manure to a Regional Anaerobic Digester: Things to Consider

### Transporting Manure to a Regional Anaerobic Digester: Things to Consider

M. Charles Gould  
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#### I. Introduction

There are few regional (centralized) anaerobic digesters in the United States. However, given the current regulatory climate, the odor reducing and nutrient stabilizing benefits of anaerobic digesters and the potential to improve farm income, more regional anaerobic digesters may come on line. Anytime manure from different farms raising the same species of animal in a given geographical area is co-mingled, biosecurity is an issue. The purpose of this publication is to offer suggestions that would control the potential movement of disease organisms and pathogens and increase loading and unloading efficiencies for a regional anaerobic digester. It is a starting point for developing a plan to minimize trucking expenses and maintain biosecurity vigilance.

Most of the points found in this publication are the result of discussions with Mr. Ken Zwald, President of Zwald Transport, Inc., Tillamook, OR and Dr. Dale Rozeboom, Associate Professor/Extension Swine Specialist at Michigan State University, East Lansing, MI. Zwald Transport is the contracted commercial hauler of manure and effluent for the Port of Tillamook Bay (Oregon) centralized anaerobic digester (see <http://www.potb.org/methane-energy.htm> for more information on the digester). Mr. Zwald said that by sharing his insights with others he hoped to help people avoid making the same costly mistakes he made.

#### II. Overview of the Transportation Cycle

It is too costly, according to Mr. Zwald, to haul materials one way. Dairy farmers providing manure to the centralized digester have agreed to accept the effluent from the digester. Thus, each farm has storage for the effluent in addition to manure storage. When a rig pulls onto a farm it unloads the effluent from the digester into a manure storage facility and then fills up with manure. In any given day this is repeated until all the manure on the farm has been hauled away.

#### III. At the Farm: Unloading effluent from the anaerobic digester and loading manure

The underlying premise in designing the loading area *is to avoid contact between manure and the truck and tanker*. With this in mind, consider the following points:

- Construct a loading platform to keep manure from coming in contact with the truck and tanker. However, should splatters or spills occur, make the loading platform easy to clean. Crushed rock in clay is not the best choice because it is too difficult to clean up.
- The loading platform should be equipped with a source of potable water to clean off manure splatters and spills, and drainage back to the manure storage facility.
- Install drive-through wheel washers.
- Determine the maximum amount of time to load and unload a tanker. For Zwald Transport that time is 5-6 minutes.

#### IV. At the Anaerobic Digester: Unloading manure and cleaning off the tanker

Time to unload manure and load effluent is the pinch point at the digester. The digester must be constantly fed. It takes careful planning to ensure a constant flow of manure. Consider the following timing and equipment points:

#### Timing: Unloading and Loading

- There are many tasks to be completed in the time allotted for a driver to unload and load the tanker before going to the next farm. Examples include filling out paperwork associated with the load (see page 5 for an example of the Zwald Transport log) and bathroom breaks.
- For Zwald Transport, a load is defined as a minimum of 4,500 gallons of manure or effluent.
- Clean the truck and tanker at the digester. It takes approximately an hour to clean a rig and a lot of force to clean manure off of metal.
- Drive clean rigs onto the farm.
- Keeping the rig clean in the first place reduces cleaning time.

#### Equipment Consideration

- Mr. Zwald recommended staying away from aluminum trailers due to stress problems associated with traveling over rough ground e.g. farm lanes. Aluminum trailers are more for transporting materials on highways, not dirt roads.
- Use knife valves, not round valves.
- Use Bauer couplings instead of ChemLock couplings.
- Use a bleeder valve in the hose to facilitate manure drainage out of the hose after loading manure into the tanker.
- Mr. Zwald said he is converting to 6 inch diameter 15 feet long sewer cleaning hoses and staying away from hard hoses. This increases manure movement capacity, which in turn decreases loading time.
- Use air cooled vacuum pumps for manure with a Total Solids content of <7%. For manure with a Total Solids content >7%, use water cooled vacuum pumps.
- In some vacuum tankers the manure swells. This affects the volume of manure that is hauled and needs to be dealt with.

#### County and State Road Weight Restrictions

- Michigan has weight restrictions (maximum gross axle loadings) on all roads as set forth in the Michigan Vehicle Code Act 300 of 1949 (MCL 257.722). In general, weight restrictions are determined by the time of year and spacing between axles. Specific weight restriction information can be found at:
  - Michigan Vehicle Code Act 300 of 1949 (MCL 257.722) [http://www.legislature.mi.gov/\(10v5upfd4cq1bh55hdxrqfmu\)/mileg.aspx?page=getobject&objectname=mcl-257-722&queryid=1945485&highlight=seasonal%20weight](http://www.legislature.mi.gov/(10v5upfd4cq1bh55hdxrqfmu)/mileg.aspx?page=getobject&objectname=mcl-257-722&queryid=1945485&highlight=seasonal%20weight)
  - Ottawa County Road Commission <http://www.ottawacorc.com/>
  - Allegan County Road Commission <http://www.alleganroads.org/>
  - Michigan Department of Transportation <http://michigan.gov/mdot>
  - County Road Association of Michigan <http://www.micountyroads.org/>
- Zwald Transport is replacing their existing fleet with three axle trucks and tankers in order to increase carrying capacity to 6,000 gallons per trip (this equates to approximately 66,000 pounds assuming one gallon of liquid manure weighs eleven pounds).

#### **V. Economics of hauling manure**

- Mr. Zwald recommended billing on a per gallon rate rather than an hourly rate.

- A typical work week is 10-12 hours per day seven days a week.
- The goal is to haul 8-10 loads per day per tanker.
- It costs Zwald Transport \$14,000/month to haul manure.
- Mr. Zwald said the furthest farm away from the digester is a one hour twenty minutes round trip (5.5 miles).

## **VI. Manure storage at the digester**

Have enough storage at the digester to provide manure for at least two days. This will keep the digester going long enough to repair equipment breakdowns and allow personnel time off for holidays or other personal reasons.

## **VII. Proposed Biosecurity Concepts**

Biosecurity is a series of management steps taken to prevent the spread of infectious disease. A strong biosecurity plan builds trust with farmers who provide manure to the digester. A biosecurity plan includes three components: cleanliness of the truck operator, cleanliness of the transport equipment and testing for diseases and pathogens in the filtrate.

### **a. Cleanliness of the Truck Operator**

The truck operator has the responsibility to implement the biosecurity plan. The operator should wear clean clothes to each farm. Boots should be thoroughly cleaned and disinfected before going on a farm. Cleanliness should begin with the operator.

### **b. Transport Equipment**

#### **1. At the digester**

The cleaning of transport equipment [meaning the truck, tanker and any equipment used to move manure (pumps, hoses, etc.)] occurs at the digester site after each load of manure is discharged into the digester. Cleaning transport equipment means:

- Washing all tires, including under each fender.
- Washing the tank, including the undercarriage.
- Rinsing out pumps and hoses used to transport manure to the tanker and from the tanker to the digester.
- Allowing time for equipment to dry to maximize pathogen kill.

#### **2. At the farm**

Transport equipment that comes onto the farm has been cleaned at the digester. When the tanker is full of manure, water is run through the pump-out equipment (pump, hoses, etc) to flush out manure. This rinsate is left in the farm's manure storage facility. As the rig leaves the farm the tires run through a vat of disinfectant.

### **c. Testing for Disease and Pathogens**

Testing for disease and pathogens in the filtrate will provide background data in the event a disease event occurs. It is proposed that testing be conducted on a monthly basis for major swine diseases, Salmonella and E. coli.

## **VIII. Conclusions**

The suggestions set forth in this document can help farmers and the digester operator work together to minimize trucking expenses and maintain biosecurity vigilance. However, what is actually implemented will need to be negotiated between the farmers and the digester operator. The suggestions in this document can serve as talking points in securing enough manure to make the digester work and help farmers feel confident that disease is not being introduced onto their farms

when manure is picked up. In the end, a weak biosecurity plan and/or the failure to minimize trucking expenses can reduce the effectiveness of a regional anaerobic digester to process manure.

## **IX. Contact Information**

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<b>Revenue Str</b>

## POTB/MEAD DAILY TIME LOG

**FAX THIS REPORT TO 842-1751 AT END OF EACH DAY**



**Start Time** \_\_\_\_\_ **End Time** \_\_\_\_\_ **Total Time Off Clock** \_\_\_\_\_ **Employee Total Time** \_\_\_\_\_

<b>Trip Start</b>	<b>When leaving PORT facility</b>
<b>Trip End</b>	<b>When unloaded and all recording, sampling, and all required tasks completed</b>

Trip Start Time POTB	Farm Name	Off Time Non Bill	On Time Non Bill	Total Non Bill Minutes	Trip End Time POTB	Total Trip Minutes	Gallons To Farm	Gallons To PORT	Off Time Explanation Driver or Truck
<b>TOTAL INCHES IN RAW TANK AT END OF DAY</b>						<b>TOTALS</b>			